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Applications Seismic UN*X (SU) Package in Seismic and Ground Penetration Radar (GPR) Data Processing

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(وَقُلْ رَبِّ زِدْنِي عِلْماً)

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Dedication

I dedicate this thesis to my Family who have been a great source of motivation and support.

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ABSTRACT

In this thesis, new seismic processing software was used to process seismic data. Seismic processing softwares are similar in their functions, which is the processing. The seismic UNIX package is new seismic processing software. It's modernity not just the functions that built in it, but also in the idea of seismic UNIX itself. The free open source software idea was first time introduced to geoscience academic community at the level of Iraq in this thesis.

The free open source idea mean that the users have the freedom to run, copy, distribute, study, change and improve the software which increase learning from each other when information is open and free exchange of ideas create collaborative environment that solve problems that no one person may be able to solve on their own. As a result the seismic UNIX called seismic Unix package because it is an aggregation of scientific curiosity of researcher in seismic processing and wave processing.

This thesis bring the practical seismic processing to the common students at anywhere while before this time it was restricted only for small group. A downloaded data was processed by seismic UNIX software in order to increase resolution, training on processing and software and use field data for processing.

The data at first was checked for geometry definition and noisy trace or missing shot which then eliminated. The seismic processing done through doing conventional tests like F-K domain and autocorrelation which show the dominant noise according to it the filter parameters were selected like dip filter and deconvolution. The other seismic processing was done through doing experimental tests and the parameters ware concluded according to satisfaction like frequency filter, data recovery and normal moveout correction. The mute also applied to the data. The end rustles of the processing is stacked section with high resolution which shows the effacing of seismic UNIX software and processing procedure. The seismic UNIX had a high flexibility in the conversion and the preparing for the futuristic processing of the non-seismic data like GPR data. As a result the seismic UNIX software is applicable and learnable for Iraqi student. I recommended being a course for under or high graduation student at the Iraqi universities.

Chapter One

Introduction

1.1 Preface

The basic principle of exploration seismology is for a signal to be generated at a time that is known exactly and for the resulting seismic waves to travel through the subsurface media and be reflected and refracted back to the surface where returning signals are detected. The elapsed time between the source being triggered and the arrival of various waves is then used to determine the nature of the subsurface layers. Sophisticated recording and subsequent data processing enable detailed analysis of the seismic waveforms to be undertaken. The derived information is used to develop images of the subsurface structure and a knowledge of the physical properties of the materials present (Reynolds, 1997).

In 1928, the seismic refraction method was introduced in to the Middle East by the British Petroleum company (at that time was called the D`Arcy Exploration). The refraction method turned out to be highly effective for finding the large oil bearing limestone structures in Iran and was used successfully thier for two decades (Dobrin and Savit, 1988).

Reflection seismic prospecting stemmed principally from the work of Reginald Fessenden about 1913. This work was directed toward measuring water depths and detecting icebergs using sound waves. The first seismic reflection survey was carried out by Karcher between 1919 and 1921 in Oklahoma, USA, until 1927, the commercial utilization of the reflection method began with survey by the geophysical research corporation of the Maud filed in Oklahoma, USA (Reynolds, 1997).

In 1938, T. Hagiwara produced a method whereby, in addition to determining the lower layer velocity, the depths to this horizon could be determined at all shot and receiver positions along a single profile. After the end of World War II, seismic reflection surveys were being undertaken in the water covered areas and open ocean. In the early 1950s marine surveys had been carried out in the Gulf of Mexico (Dobrin and Savit, 1988).

Presentation of tape recorded data on time corrected record sections became common practice during the late of 1950. In 1963, digital equipment was first employed on a widespread basis. Another highly significant development was common depth point recording, in which signals from different shot point receiver pairs are time corrected and composited for reduction of noise. This technique was invented by Harry Mayne in early 1950, but it did come into widespread use until about a decade later (Dobrin and Savit, 1988).

Major developments in the seismic methods have come about by revolutions within the computing industry. Processing once thought possible only by mainframe computers is now being handled on personal computers and stand-alone workstations. With the vast increase in computer power, currently at a rate of an order of magnitude every two years, has come the ability to process data far more quickly and reliably (Reynolds, 1997).

Because of its critical importance for modern data acquisition and analysis, geophysical software development has grown into a major industry. Many companies, from majors such as CGG, Landmark, and Schlumberger to numerous smaller vendors provide software solutions and services for numerous applications. Traditionally, geophysical software has been highly specialized for certain applications (e.g., field QC, reflection seismic processing, modeling, or interpretation). However, with growing concentration of computational power, the present and future trends in geophysical software are clearly for reintegration, allowing a researcher instant access to the entire data analysis and interpretation. Another important trend is the explosive growth of open source software developed and supported by the community (Chubak ,2006). The open source software is important for rapid exchange of ideas, development, and response to the needs of the community. The success of open source software in recent years has demonstrated that it can meet and from many aspects exceed the quality of commercial solutions. With fast development cycles and code

contribution directly from users, new features can be quickly implemented and vetted. In many businesses, including hydrocarbon industries, reducing cost is of high priority. Although hydrocarbon industries appear able to afford the expensive computing infrastructure and software packages used to process seismic data in the search for hydrocarbon traps, it is always imperative to find ways to minimize cost. Seismic processing costs can be significantly reduced by using inexpensive, open source seismic data processing packages (Chubak, 2006).

Seismic Unix (SU) is perhaps the best-known open-source geophysical package. It was developed and maintained by the Center for Wave Phenomena (CWP) consortium at the Colorado School of Mines. It contains a large number of tools in a well-documented and maintained package. Each tool is an independent UNIX program that must adhere to a strict input/output structure as the data is passed using file pipes (pipes mean connect standard output of one command to standard input of another command).

The seismic industry has been impressively dynamic and creative during its 60-year history. Although it is relatively a small sector within the oil and gas industry at large, it has made the most significant impact on increasing proven reserves and reserve-production ratios worldwide (Yilmaz, 2001).

1.2 Seismic reflection method

The purpose of acquiring and processing seismic data is to learn something about the earth's interior. To understand certain aspects of the Earth we initially need to figure out some specific relations between the intended targets and measurable parameters. Then our first step is to conduct data acquisition designed for the problem, our second step to use data processing to identify and enhance the desired signal, and our third step to conduct data interpretations as in Fig (1.1) based on the processed data (Zhou ,2014).

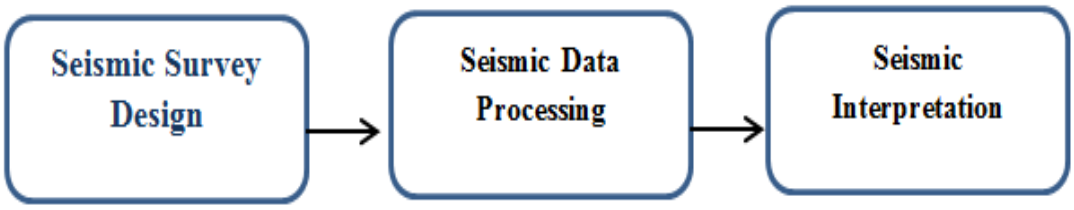


Figure 1.1: Seismic reflection procedure chart.

In reality, the processes of data acquisition, processing and interpretation are interconnected and complement each other as in Fig (1.2).

After data acquisition and before data processing, we need to conduct the process of data quality control (QC). This involves checking the survey geometry, data format, and consistency between different components of

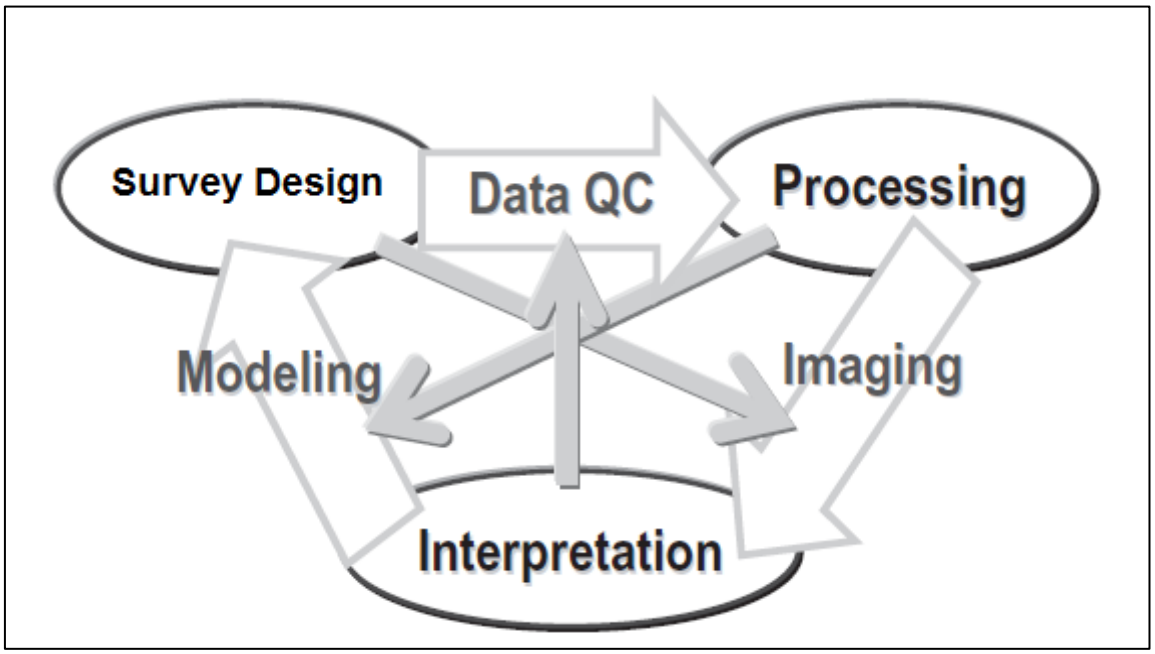


Figure 1.2: Seismic method relationships (modified from Zhou ,2014).

the dataset, and assuring ourselves that the quality and quantity of the dataset are satisfactory for our study objectives. The data QC process is typically part of the pre-processing. After pre-processing to suppress various kinds of noise in the data, seismic imaging is conducted to produce various forms of imagery for the interpretation process. The seismic imaging methods include seismic migration, seismic tomography, and many other methods of extracting various seismic

attributes. Some people call seismic imaging methods the advanced processing (Zhou, 2014).

After data interpretation, we often conduct seismic modeling using the interpreted model and the real data geometry to generate predictions to compare with the real measurements, and hence further verify the interpretation (Zhou ,2014).

As a results, the seismic data processing have big influence in the seismic exploration procedure because of the following reasons (Upadhyay, 2004).

1. Simultaneous recording of noise along with reflected signals.
2. Modification of the reflection signal due to propagation effects (spherical spreading, anisotropic wave propagation, and or viscoelastic dissipation).
3. Variation of reflection signal amplitude by seismic source receiver directivity.
4. Interference between reflected signals or between the primary reflections and multiples.
5. Necessity to bring in focusing of the weak reflection events (stacking).
6. Artifacts in interpretation results, produced as a result of the method of data acquisition or processing or both.
7. Necessity to search for clues or patterns in the record (like diffractions, correlations or phase relationships).
8. Necessity to assign real locations of the origin of reflected signals (migration).
9. Necessity to appropriately account for geometry of reflectors, or reflector curvature.
10. Need for preparing depth sections (velocity analysis).

1.3 Open source softwares

The terms free software and open software are often used interchangeably. However, although a majority of software is both open and free there are a difference between them both in philosophy and in the licenses that fall within each. The free software movement is at its roots about the users freedoms whereas open source focuses on making software better from a practical perspective by allowing access to the code so that others to improve it. These two views may lead to the same outcome in how the software is treated from a copyright perspective but the goals for getting to that outcome are slightly different (Hahn, 2014).

The concept of free software began in 1984 with Richard Stallman, a Massachusetts Institute of Technology (MIT) researcher. He was concerned that computing would be dominated by a few powerful people if software were all proprietary. He considered software scientific knowledge that should be shared and distributed to further innovation in computer science. In 1984, he left MIT and began the GNU Project and the Free Software Foundation (Hahn, 2014).

The most important characteristic of free software is the philosophy for why software should be free and what free means. The philosophy of free software is one that respects users freedoms while benefiting society by promoting sharing and cooperation. The term free software is about freedom, not price. A program is free if you can run the program for any purpose you have the freedom to modify the program (requiring access to the source code), you have the freedom to redistribute copies with or without a fee, and you have the freedom to distribute modified versions of the program so the community of software developers can benefit from improvements. Note that the freedom to sell copies of software is permissible because the term free here does not refer to price so there is nothing prohibiting someone from generating revenue from free software the founders of the free software movement believed such revenue could ideally be used to generate new free software projects. However, to thwart

businesses from co-opting free software for their exclusive commercial use, Stallman created the GNU General Public License (GPL) (Hahn, 2014).

1.4 An overview on open source seismic softwares

Many seismic processing softwares are available. Table (1.1) give a summary of

Table (1.1): Free Seismic processing software (Wikipedia, 2017).

Name	Description	Originator	License	Platforms	Language	Notes
Madagascar	Multidimensional data analysis including seismic processing	Sergey Fomel and others	GPL	Cross-platform	C, C++, Python	Programming Interfaces to Fortran 77, Fortran 90, Python, Java, MATLAB, Julia.
FreeUSP	Seismic processing	Amoco, BP	Custom	Unix, Linux	Fortran 77, C	
FreeDDS	Seismic processing	Amoco, BP	Custom	Unix, Linux	Fortran 77, C	Generic format (SEGY, SU, SEPlib, USP)
PSEIS-OSS	Parallel seismic processing	Randy Selzler	GPL	Unix, Linux	Fortran 77, C	Generic format (SEGY, SU, SEPlib, USP, Madagascar)
CWP/SU (Seismic Un*x)	Seismic processing	Stanford, Colorado School of Mines	BSD-style	Unix, Linux, OS X, Cygwin 32	C, some Fortran 77	World's most widely used (82 countries and territories).
CPSeis	Seismic processing	ConocoPhillips	MIT	Cross-platform	Fortran 90, C++	
SPARC	Seismic processing	ARCO	GPL	Cray	Fortran	
SEPlib	Seismic processing	Stanford University	Custom	Cross-platform	Fortran, C	
GeBR	Seismic processing	Various contributors, Brazil	GPL	Linux	C	Interfaces with SU, Madagascar, etc.
OpenSeaSeis	Seismic processing	Bjorn Olofsson, now property of the Colorado School of Mines	BSD-style	Linux, Windows, OS X	C, C++, Java	Interfaces with SU data. Reads most common SEGY and a subset of SEGD formats.

these softwares with their license type and programming language used to program them. The order of these program are listed arbitrary. Some of them like FreeUSP and FreeDDS each of them are a seismic processing system on Unix developed to serve research needs in the areas of signal analysis and wave field imaging (www.freeusp.org). USP was founded by Amoco oil company are stopped updating due to finishing the support of the originator. Others like CWP/SU, Madagascar and SEPlib still in progress. Madagascar is an open-source software package for multidimensional data analysis and reproducible computational experiments. Its mission is to provide a convenient and powerful development platform and technology transfer tool for researchers working with digital image and data processing in geophysics and related field (Chubak ,2006). SEPlib another well-known project is the Stanford Exploration Project library (SEPlib). It is similar to Seismic Unix in basic design and it was actually the parent project to SU. File pipes are used to pass data between different programs, which each serve as a processing tool (Chubak ,2006). Programs must read and write the specified format to be compatible with other SEPlib programs.

The seismic Unix (SU) is used in this thesis because it is widely used, easy to install and complete in its implementations.

1.5 Seismic data format

Seismic data is processed on the computer and therefore the data must be stored on a device. The data storage can be done in many ways, and in general there are quite a lot of ways to do that. Because the amount of data that are dealing with in seismic, it is important to do this in an efficient way. Already early in the use of computers seismic data is stored in a format specific to seismic data. And fortunately to the seismic industry, the formats introduced became standard. The standards in the seismic industry are made by a special standardization committee of the Society of Exploration Geophysicists (SEG), which is an

American society. Quite a few standards came out of this committee, and two of them became very popular. These are the standards SEG-D and SEG-Y. Since in the early days the disk capacity was rather small compared to the tape devices, hardly any format existed for seismic data stored on disk. However, times have changed and some standards have been defined, although not very much used. Many processing packages have their own internal format, but lately the standard defined for tape devices, SEG-Y, is used for disk files as well. However, the data is unformatted written on disk, so it depends on what kind of internal word representation is used on the computer. SEG-Y is, by definition, IBM floating point. The other disk format for disk storage is SEG-2 which is unfortunately only defined for a PC environment.

1.5.1 SEG-Y format

The other tape standard mentioned is SEG-Y as in Fig (1.3). This standard has been used extensively (Barry et al.,1975) . A very nice feature of the standard is that it is not only a published standard, but it has also been adopted as a standard for the oil industry. This has made data communication very simple, and most data transfer takes place via SEG-Y (Barry et al., 1975).

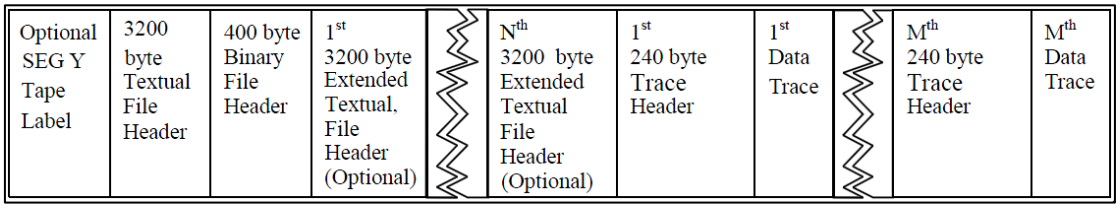


Figure 1.3: Seismic data format SEG-Y standard structure (SEG comment ,2002).

SEG-Y is a tape standard which was defined on the top of that time standard of IBM-floating point, this means that floating-point numbers are stored as such. A SEG-Y tape consists of two so called real headers, so these are headers which occur only once on a tape. There are two real headers, one being an EBCDIC header of 3200 bytes, and another being a binary header of 400 bytes. In the EBCDIC header one can put general information about the data on the tape,

such as where it was shot and when, and by who, and so on. How this is filled is completely arbitrary, as long as it is in EBCDIC (which can easily be converted to ASCII). For the binary real header this is different. In this header the way is built up is very precise. In this header there are a few positions which are recommended to be filled. These are data such as line number, sampling,number of samples per trace and so on (Barry et al., 1975).

The next blocks on a SEG-Y tape are trace blocks which consists of a trace header and the values of the trace itself. This trace header is by definition 240 bytes large, and information of the trace can be set in this header. Again, some positions are recommended to be filled and thus must be set. There are totally six fields which must be set, namely trace sequence number in the line, the original field record number, the trace number within the original field record number, a trace identification code, the number of samples, and the sampling interval; optionally, other information like source and receiver coordinates, water depth, elevation information, etc. After this header the values of the trace are given in one record, of course as many as given in the header. After these trace blocks comes the header of the next trace, and then the values of that next trace, and so on (Barry et al., 1975).

1.5.2 SU format

The SU storage format is used only in the Seismic Unix (SU) programs (Stockwell and Cohen, 1999). There is a binary data file with no file header and one record for every trace. Each record consists of a 240-byte header section and a data section. The trace header is similar in structure to the SEG-Y trace header. The data section consists of an array of 2-byte signed integers, one integer for every data sample point. Floating point values can also be used. The number of sample points is variable and does not have to be a power of 2 (Stockwell and Cohen, 1999).

The SU data format is based on the trace portion of the SEGY format. The primary difference between the SEGY traces and SU traces is that the data portion of the SU format are floats, written in the native binary float format of the machine you are running SU on. SU data consists of the SEGY traces only the ebcdic and binary real headers are not preserved in the SU format, so simply redirecting in a SEGY file will not work with any SU program (Stockwell and Cohen, 1999).

1.6 Previous work

There are many studies done using seismic Unix in multi branches not just seismic data processing but also sonar and ground penetration data also.

Bording (1995) use seismic Unix to test the different geological environments by creating models (forward method) of them and calculate their seismic response with comparative of inversion method.

Galway (2000) use seismic Unix to process marine seismic data in order to combine it with sonar data of the area by using the GIS system. He find that this increase the performance of interpretation and facilitate the storage of the data in interactive environment.

Beckett (2004) use matched filters using seismic Unix as a platform. He find that the matched filter was successful in simultaneously canceling the energy in seismic events with a flat AVO response, and enhancing events with significant AVO response.

Forel, etal., (2005) use seismic Unix to develop processing techniques for inverse and foreword seismic data. The book is very interesting and has many shell scripts implement seismic data modeling and inversion.

Soupios and Toth (2005) use seismic Unix to process shallow seismic reflection marine data in order to get information about the stratigraphy of the sedimentary layers.

Mukherjee and Banerjee (2006) use seismic Unix to create synthetic seismic data in order to test and compare different migration techniques. They find that Fast Fourier Finite Difference as well as Finite Difference techniques provide better imaging of the reflectors as compared to f-k band Gazdag and Phase shift migration.

Öhman, etal., (2006) use seismic Unix two-dimensional reflection seismic processing methods to refraction seismic data obtained from Finland to locate the ideal sealing trap for nuclear fuel disposal and to ensure no faults occur in it.

Yedlin, etal., (2010) used seismic Unix in processing same ground penetration radar data which obtained from different acquisition antenna system.

Rubio (2010) use seismic Unix to test whether geologic interpretation could be improved by applying seismic attributes. He find that attributes can help further define geologic features.

Aziz, etal., (2011) use seismic Unix in comparative study with another open source processing software. They process seismic data with high performance computer (HPC) cluster and compare the results. They find reduction of costs in seismic data processing can be achieved by using open source seismic data processing packages like SU because they are practically no cost to use, and exploit the power of parallel processing.

Schleicher (2012) us seismic Unix to reprocess 2D line data obtained from Alaska. The 2D line data was already processed by commercial software. He find that the results are similar to the results obtained in 1981 using GSI's (Geophysical Service Incorporated company) proprietary software.

Petrov and Berberova (2012) use seismic Unix to process ground penetration radar data. So they get better understand for ecology and protection of infrastructure of small earth embankment dams and river dikes.

Torres and Goyes (2013) use seismic Unix to introduce seismic forward modeling as a powerful tool to investigate the seismic wave propagation in structural geologic cross section. He find events with high dips generate pitfalls in seismic sections, these can be corrected with depth migration and velocity model better.

Rodríguez (2013) use seismic Unix to create and process models to development of new techniques with high precision that enable the record of subtle changes in seismic properties. He find that refraction time-lapse seismic method aims the estimation of reservoir velocity changes at a much lower cost than conventional 4D seismic monitoring.

Lorenzo, etal., (2014) use seismic Unix to make velocity analysis of seismic refraction data and compare the result with depth model of flood protection.

Bashir, etal., (2016) use seismic Unix to examine the accuracy of using, the eikonal solver and paraxial ray tracing traveltime computation in pre-stack Kirchhoff depth migration. The results demonstrate the significance of using hybrid traveltime computation and provide more matching results.

Yagci (2016) use seismic Unix to reprocess multi-channel land seismic data in order to enhance signal to noise ratio and determining the correct processing techniques and parameters. He find that butterworth minimum phase filter was good to solved the low amplitude, spiking deconvolution and the prediction error filter recovered the low amplitudes on velocity semblances and increased the accuracy of velocity picking. Gazdag migration were used for structural interpretation because the migration was successful for shallow and the deep parts at the same time, unlike the Stolt migration.

1.7 Aims of the study

1. Attempting to create a workflow suitable for high resolution seismic data processing
2. Simulation and training of Seismic data processing by installation and prepare the Unix platform for seismic Unix software by put it in an easy format within PC (personal computer).
3. Applied the SU package to real 2D seismic profile data and ground penetrating radar.

Chapter Two

Seismic Unix

2.1 Preface

Analysis of geophysical data nearly always involves application of sophisticated and multi-stage processing and inversion. With volumes of data and resolution of the datasets exploding in the recent years in nearly every field, the demand for computer packages facilitating, handling, processing, analysis, and interpretation of large and complex datasets is growing. This particularly applies to exploration seismology, where development of processing packages has grown into a thriving industry. A number of integrated software systems, mostly specialized and streamlined for reflection seismic data, are available (Chubak, 2006).

Although highly advanced, commercial processing packages are still built for specialized industry users. For a broader geophysical community, reliance on such software may not be satisfactory for several reasons. First, while being highly efficient in their primary fields of application (typically, 2-D or 3-D common mid-point reflection data processing), commercial packages could become awkward in handling other types of data. Examples from seismology include wide-aperture reflection, refraction or earthquake data, where native support for flexible, multi-component processing, spherical-Earth geometry, and travel-time analysis is critical. Second, commercial packages often require installation of other systems (e.g., databases or rendering systems) whose support could be difficult or expensive in a university environment. And finally, licensing costs are often prohibitive، particularly when utilizing large multi-processor computer systems(Chubak, 2006).

Open-source seismic processing softwares provides a low-cost alternative to commercial software, with an appropriately directed development, and an ability to adapt to the changing research needs.

2.2 Seismic Unix

Seismic Unix is a self-contained open source software environment (softwares package) for seismic research and data processing used by exploration geophysicists, earthquake seismologists, environmental engineers, software developers and others. It is used by scientific staff in both small companies and major oil and gas companies, and by academics and government researchers (stcokwell and cohen, 1994).

The Seismic Unix (SU) project is partially funded by the Society of Exploration Geophysicists (SEG) and by the Center for Wave Phenomena (CWP), Department of Geophysical Engineering and Colorado School of Mines. Past support for SU has included these groups, as well as the Gas Research Institute (GRI).

The SU package is free software, meaning that you may have unrestricted use of the codes for both processing and software development. The package is maintained and expanded periodically, with each new release appearing at 3 to 6 month intervals, depending on changes that accumulate in the official version at CWP. The package is distributed with the full source code, so that users can alter and extend its capabilities(stcokwell and cohen, 1994). The philosophy behind the package is to provide both a free processing and development environment in a proven structure that can be maintained and expanded to suit the needs of a variety of users. The package is not necessarily restricted to seismic processing tasks. However, a broad suite of wave-related processing can be done with SU, making it a somewhat more general package than the word “seismic” implies. SU is intended as an extension of the Unix operating system, and therefore shares many characteristics of the Unix, including Unix flexibility and expandability (Al-Shuhail, 2007).

The fundamental Unix concept is that all operating system commands are programs run under that operating system. The idea is that individual tasks be identified, and that small programs be written to do those tasks, and those tasks alone. The commands may have options that permit variations on those tasks, but the fundamental idea is one-program with one-task (Al-Shuhail, 2007).

This decentralization has the advantage of minimizing overhead by not launching single applications that try to do everything, as is seen in Microsoft applications, or in some commercial seismic utilities. For example, Unix has the added features of supporting a variety of shell languages, making Unix, itself, a meta-language. Seismic Unix benefits from all of these attributes as well. In combination with standard Unix programs, Seismic Unix SU programs may be used in shell scripts to extend the functionality of the package (Al-Shuhail, 2007).

Of course, it may be that no Unix or Seismic Unix program will fulfill a specific task. This means that new code has to be written. The availability of a standard set of source code, designed to be readable by human beings, can expedite the process of extending the package through the addition of new source code (Al-Shuhail, 2007).

2.2.1 Seismic Unix Structure

Seismic Unix is a group of seismic processing applications complemented with a variety of applications for manipulating and displaying seismic data. It is also provides a robust set of subroutine libraries that greatly facilitate the development of new applications. The applications provided with seismic Unix are classified according to their purpose (Murillo, 1996).

Fig (2.1) shows the organization of the directories of the seismic Unix software. the main directory of the distribution package contains four subdirectories. The bin subdirectory contains the executable for each one of the applications provided with seismic Unix. The directory include contains all the include files (i.e. .h files) necessary for compiling programs that utilize functions of the subroutine libraries.

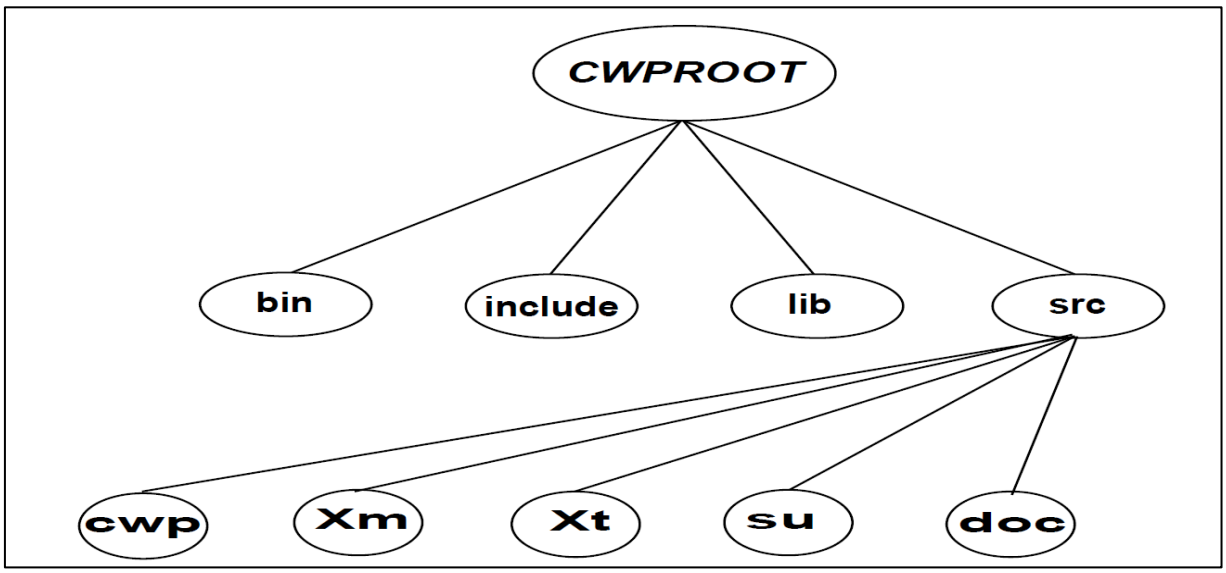


Figure 2.1 : seismic Unix structure (Murillo, 1996).

The lib subdirectory stores each one of the libraries distributed with the software. The source code for each one of the main applications provided with seismic Unix, along with the corresponding makefile used to generate its executable, are stored under the directory src. The applications are organized in this subdirectory according to their purpose and also according software requirements (some applications require windowing capabilities). The directory cwp contains utility programs developed using functions of the different libraries provided with seismic Unix. It also contains programs that illustrate how to use some of those functions. The subdirectory Xm contains the source code of applications requiring the motif window manager software. the subdirectory Xt contains those applications requiring X-window software libraries. The SU subdirectory contains the source code of all the strictly

geophysical applications, which constitute the core of the system itself (Murillo, 1996).

The basic concept behind the main applications composing SU is that each one of them is intended to be used as any other Unix command, which makes them suitable to be included in any conventional Unix shell script. In this way, the user can make effective use of them by simply exploiting the programming facilities provided by most of the Unix-shell programs currently available (i.e. csh, tcsh, ksh) (Murillo, 1996).

The seismic Unix components are classified in to (Murillo, 1996).

1. Main programs: These programs constitute the core of the system. There are more than one hundred programs available, ranging from applications to display seismic trace datasets to advanced seismic migration and modeling codes.
2. Support subroutine libraries: The most important subroutine libraries are lipcwp.a, lipsu.a, and libpar.a. these libraries implement a wide range of functions, ranging from basic functions to allocate space for multidimensional arrays to more complex numeric calculations like mixed-radix fast Fourier transformation. Supporting functions for performing tasks such as parameter reading and modification of trace headers are provided as well.
3. Documentation programs: There is a complete set of document files that provides the user with help about almost anything in the package. Virtually all seismic Unix program give information about themselves when you type the name of the program without any arguments. Seismic Unix provides an utility called sudoc that lists the self-documentation of all programs in the package. Subroutines and the few mains and shell scripts that do not show a selfdoc will have a sudoc entry.

4. Shell tools and utilities: The development and wide use of seismic Unix has produced a lot of utility programs useful in the developing of new applications as well as in the manipulation and visualization of seismic data.

2.2.2 Seismic Unix Working Environment

Any program that has executable permissions and which appears on the users PATH may be run by simply typing its name on the command line. The (path) or (PATH) is the value variable tells where the working shell to look for executable files. After the path value the $ symbol will represent the beginning of the command line prompt. The user does not type this $. Because there are a large variety of possible prompt characters, or strings of characters that people use for the prompt, it is show here only the dollar sign $ as a generic command line prompt The command prompt is saying (Type program name here) (Stockwell, 2016).

The proper input for a command line is an executable file, which may be a compiled program or a Unix shell script. These input can be managed by Unix tools which is:

1. The vertical bar sign | : Is called a (pipe) on all Unix-like systems. Output sent to standard out may be piped from one program to another program.
2. The greater than sign > : Is called redirect out which reads from standard input and writes to the file whose name is supplied to the right of the symbol.
3. The less than sign < : Is called redirect in reading the input from the file which is on left side of the symbol.
4. The ampersand sign & : Indicates that the program is being run in background. It sited at end of programs command. When this sign used

multi programs command run at the same time if, not used only one programs command can be run.

2.2.3 Seismic Unix Viewing Data Abilities

Proper presentation can enhance features we want to see and suppress parts of the data that we are less interested in, accentuate signal and suppress noise Improper presentation, on the other hand, can take turn the best images into something that is totally useless (Stockwell, 2016). The Seismic Unix package has a collection of graphics utilities for plotting data. Which is (Stockwell, 2016).

1. Contour plots Fig (2.2).
2. Gray or colorscale image plots Fig (2.3).
3. Wiggle trace plots Fig (2.4).
4. Line or symbol graphs as in Fig (2.5).
5. Movies it could be used in 4D processing.
6. 3D cube plots are a combination of wiggle or image plots.

It will be discussed here the heavily used plotting methods.

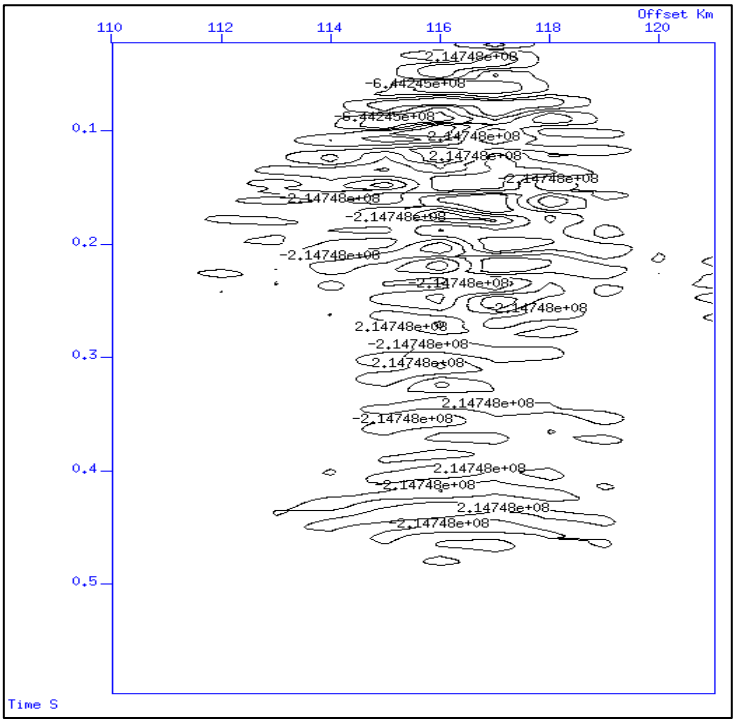


Figure 2.2: Example of seismic Unix contour map plotting.

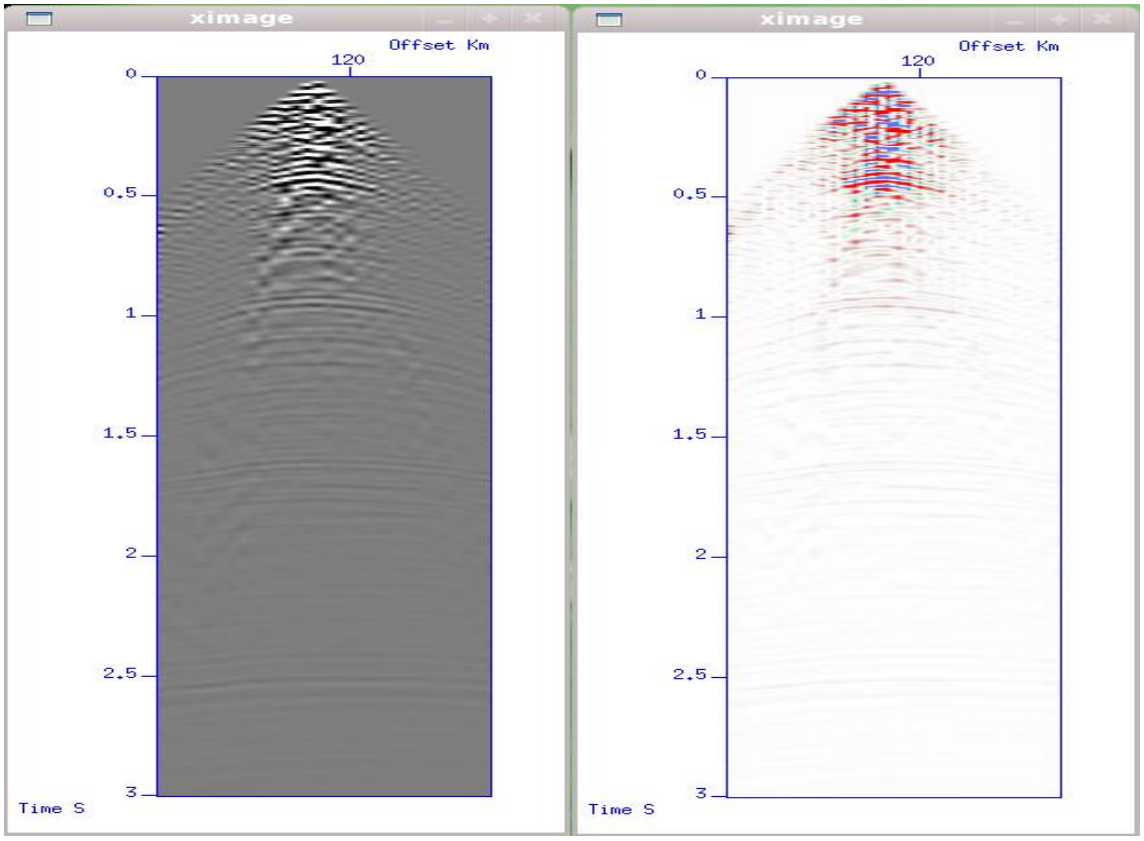


Figure 2.3: Example of seismic Unix gray & color scale image plotting.

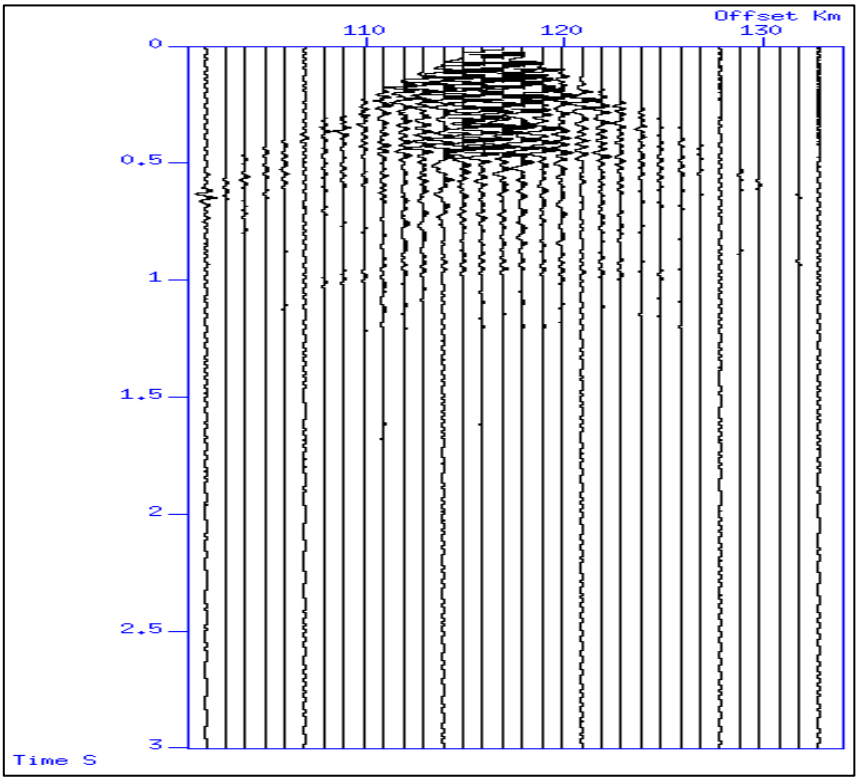


Figure 2.4: Example of seismic Unix wiggle trace plotting.

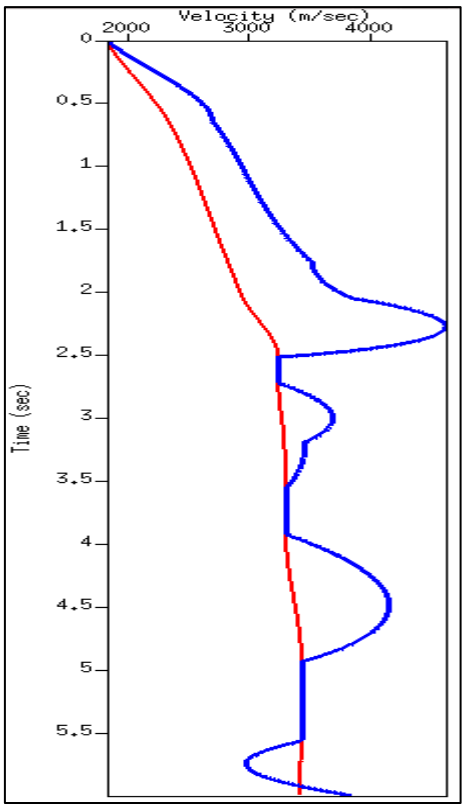


Figure 2.5: Example of seismic Unix graph plotting.

2.2.3.1 Wiggle traces Plot

A common mode of presentation of seismic data is the "wiggle trace." Such a representation consists of representing the oscillations of the data as a graph of amplitude as a function of time, with successive traces plotted side-by-side like in the Fig (2.6).

Amplitudes of one polarity (usually positive) are shaded black, whereas negative amplitudes are not shaded. Be aware that such presentation introduces a bias in the way the data be viewed , accentuating the positive amplitudes. Furthermore, wiggle traces may make dipping structures appear fatter than they actually are owing to the fact that a trace is a vertical slice through the data.

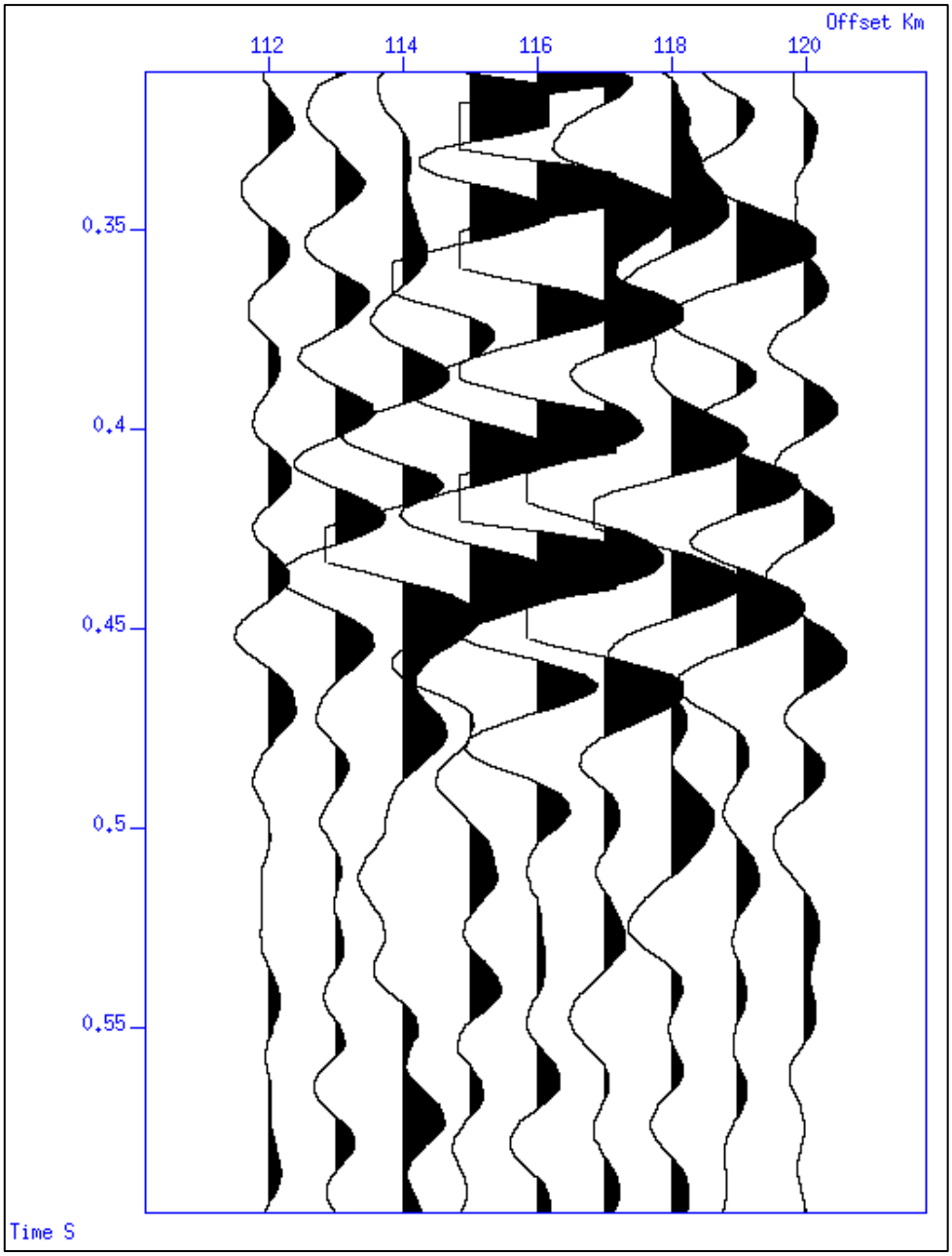


Figure 2.6: Zoomed section in the wiggle plot.

2.2.3.2 Image Plot

The seismic data may be thought of as an array of floating point numerical values, each representing a seismic amplitude at a specific (t, x) location. A plot consisting of an array of gray or color dots, with each gray level or color representing the respective value is called an image plot as in the Fig (2.3). Image plots usually used for datasets of more than 50 traces and use wiggle traces for smaller datasets.

2.2.4 Seismic Unix Processing Abilities

Seismic Unix have many processing tools that are used for processing and others used for developing new tools for processing. These are some of them:

1. Amplitudes tools.
2. Attributes Parameter Estimation tools.
3. Convolution and Correlation tools.
4. Data Compression tools.
5. Data Conversion tools.
6. Datuming tools.
7. Decon Shaping tools.
8. Dip Moveout tools.
9. Filtering tools.
10. Headers Manipulation tools.
11. Interp Extrap tools.
12. Migration and Inversion tools.
13. Multicomponent tools.
14. Noise Creation tools.
15. Arithmetic Operations tools.
16. Picking tools.
17. Stacking tools.
18. Statics tools.
19. Stretching Moveout and Resample tools.
20. Supromax tools.
21. Synthetics Waveforms Testpatterns tools.
22. Tapering tools.
23. Transforms tools.
24. Velocity Analysis tools.
25. Vertical Seismic Profileing (VSP) tools.
26. Windowing, Sorting and Muting tools.

27. Delaunay Triangulation Materials Modeling method tools.
28. Tetrahedra Materials Modeling method tools.
29. X-windows Graphics for Delaunay Triangulation.
30. Wavelet Packet Compression tools.
31. 2D Discrete Cosine Transform Compression tools.

2.3 Unix OS

Unix is an operating system (OS). It manages the way that computer works by driving the processor, memory, disk drives, keyboards, video monitors, etc. and by performing useful tasks for the users. Linux was initially created as a hobby by a young student, Linus Torvalds, at the University of Helsinki in Finland. He began his work in 1991 when he released early version of Linux on the Internet (Taylor and Armstrong,1997).

Since then, a number of people, collaborating over the internet, have contributed to the development of Linux, all under the control of Torvalds. Because Linux is free and the source code is available, it became an early alternative to other Linux (Sobell, 2010).

Unix is a free software packages under the auspices of the Free Software Foundation (FSF). FSF's goal is stable, platform-independent software that is free, high quality, and embraced by the user community. Provide simple, yet powerful utilities that could be pieced together in a flexible manner to perform a wide variety of tasks. Unix is designed for multiple users. That is multiple users may have multiple tasks running simultaneously. Its original purpose was to facilitate software development. It is the primary OS used by physical scientists everywhere, and all supercomputing facilities use it (Sobell, 2010).

The Unix is formed of three essential components (Sobell, 2010).

A. The Kernel: is the core of the Unix system. Loaded at system start up (boot); manages the entire resources of the system. Examples of what it does are: interpreting and executing instructions from the shell, managing the machine's memory and allocating it to processes, scheduling the work done by the cpu's.

B. The Shell: whenever you login to a Unix system you are placed in a shell program. The shell is a command interpreter; it takes each command and passes it to the operating system kernel to be acted upon. It then displays the results of this operation on your screen. Several shells are usually available on any Unix system, each with its own strengths and weaknesses. Examples are the Bourne Shell (sh), C Shell (csh), and Bourne Again Shell (bash).

C. Utilities: Unix provides several hundred utility programs, often referred to as commands. The commands accomplish universal functions such as printing, editing files, etc.

2.4 Shell Scripting

Unix is an hierarchical operating system that runs a program called the Kernel that is the heart of the operating system. Everything else consists of programs that are run by the Kernel and which give the user access to the Kernel and thus to the hardware of the machine. The program that allows the user to interface with the computer is called the "working shell." (Stockwell, 2016).
Normally shells are interactive. It means shell accept command from you (via keyboard) and execute them. But if you use command one by one (sequence of 'n' number of commands) , you can store this sequence of command to text file and tell the shell to execute this text file instead of entering the commands. This is known as shell script. The shell script are important

because, shell script can take input from user, file and output them on screen, useful to create our own commands.

save lots of time, to automate some task of day today life and system administration part can be also automated (Gite, 2002).

Most seismic Unix programs read from stander input and write to stander output. Therefore one can build complex processing flow by simply connecting seismic Unix programs with Unix pipes. Most flows are lengthy and involve many parameter settings, it is convenient to put the seismic Unix commands in a shell executive file (Scales, 1997).

Chapter Three

Theoretical Background

3.1 Preface

In this chapter a summery for the description of common terms used in seismic processing and its related seismic Unix commands. The commands are presented in (Arial) Bold font.

Seismic data processing techniques are designed to discriminate, separate, or otherwise attenuate the noise and enhance the signal. Seismic data processing converts the acquired seismic signals to a representation of the subsurface geology (Aminzadeh and Dasgupta, 2013).

Corrections for the location of the source and receivers are made and the data converted to consistent datum either at sea level or some other reference datum. The source and receiver geometry is converted to make them collocated by using a time correction based on the distance they are separated. These are known as geometric corrections. In addition to geometric corrections, data processing also consists of signal processing of the traces. This improves the signals while reducing the recorded noise in the data.

The interpretation is only as good as the quality and accuracy of the processing of the data. The main components in data processing are signal conditioning filtering, inverse-filter or deconvolution, to extract the seismic reflectivity series for layer boundaries, correction, gaining, common midpoint stacking and data migration for image focusing. Signal processing assumes that seismic traces are reflectivity series of the earth layers convolved with distorting filters. Deconvolution improves vertical resolution by collapsing the seismic wavelet and removes a particular type of distortion. This process provides better results when sonic logs are available, or further assumptions of the input signal are made (Aminzadeh and Dasgupta , 2013).

Stacking uses the survey location of recorded data and uses velocity analysis to correct for the travel delay in the distance for the source receiver geometry, also

known as normal move out correction (NMO) and statics correction. The stacking or summing of amplitudes after the offset correction results in increased signal quality and significantly lowers the random noise. Either before or after stacking, seismic migration is performed. Migration allows seismic events to be relocated in either space or time to the location the event occurred in the subsurface rather than the location that it was recorded at the surface, thereby creating a more accurate image of the subsurface.

The process can involve hundreds of different processing steps as in Fig (3.1) and can take several weeks of dedicated computer time to complete. The data editing is to eliminate noise and selectively remove bad data. The filtering approaches that take advantage of temporal and spatial differences between the noise and the desired reflection signals. On land, cultural noise from roads, power lines, buildings, and human activity, as well as ambient noise from wind and other natural causes can be attenuated with selected filtering and data editing approaches. After data editing, seismic data are typically corrected for sensor and source effects followed by a series of processes designed to isolate primary reflection events and account for the propagation effects between the source, the receiver, and the reflecting point of interest (Aminzadeh and Dasgupta, 2013).

Propagation effects include the loss in amplitude as the wave propagates from the source down to the reflecting horizon, the scattering and travel time effects that occur as the wave travels through different subsurface strata. Another component of data processing is the elimination of coherent noise, also referred to as multiple suppression. Coherent noise is energy generated by the seismic source and received by the detector which is not a primary reflection. Examples of coherent noise, some of which can be near-surface guided waves such as ground roll, non-primary arrivals such as multiples, mode conversions, and head waves. Coherent noise can be particularly difficult in land surveying.

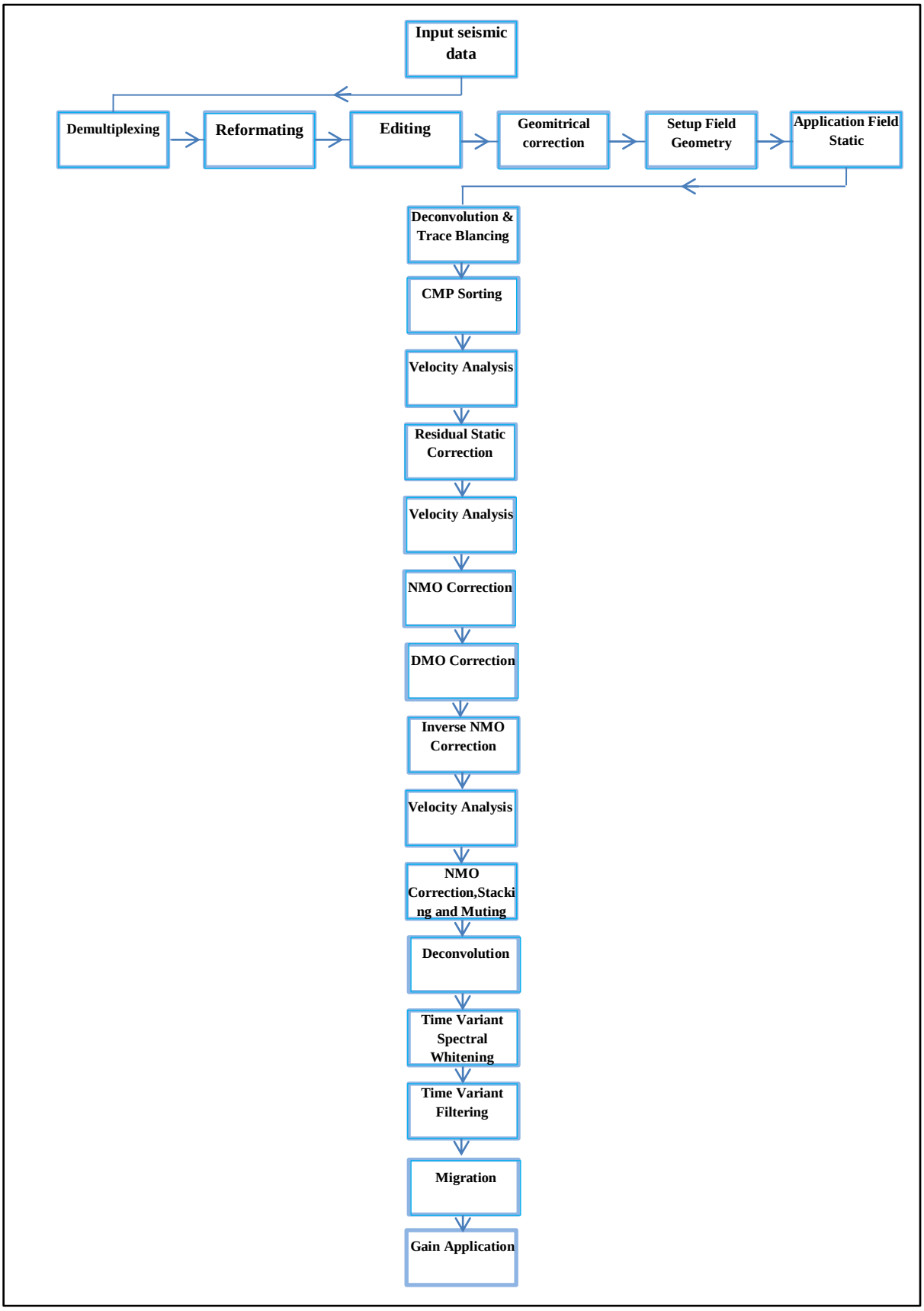


Figure 3.1: Standerd seismic processing flow (modified of Yilmaz, 2001).

The complex weathering in the near surface can be a major instigator of coherent noise modes. Typically, coherent noise is much less troublesome for offshore surveys, and, in general, offshore surveys have higher data quality than land surveys.

3.2 Data conversion

The data format that is expected by all the applications of the Seismic unix it is su format which is consists of SEGY format traces written in the native binary format of the machine you are running the programs on.

To process a seismic data by seismic unix it should be converted to su format by using segyread application. The command is:

```
$ segyread tape=data.sgy verbose=1 endian=0 | segyclean > data.su
```

tape: input tape device or segy filename. In our case data.sgy is filename.

verbose: related how segyread work trace by trace or group of traces. In our case chose group of traces by make it =1.

endian: this option related to big endian or little endian machine.

segyclean: this application used to zero out unassigned portion of the trace headers.

Successful execution of this command should produce three files: data.su that contains the seismic traces, binary that contains some binary information, and header that contains header information about the line.

When reading a SEGY tape, or datafile, should be aware of the byte-order (endian) of the machine you are running on. The so-called ``big-endian'' or high-byte IEEE format is found on SGI, SUN, IBM RS6000, and all Motorola chip-based systems. The ``little-endian'' or low-byte systems are systems that are

based on Intel and Dec chips. You will also need to know what unix device your tape drive is.

SU data consists of the SEGY traces only. The ebcdic and binary real headers are not preserved in the SU format, so simply redirecting in a SEGY file will not work with any SU program.

3.3 Data editing

In real data there may be bad traces or missing traces. Some shots may be bad as in Fig (3.2), or there may be consistent or systematic errors in the data.



Figure 3.2: Three shots and the mid shot is dead as shaded by the red arrow.

The processer should check the data by divided it in to groups of shots. The divided groups checked one by one by viewing them. In this way the dead shot and the noisy traces as in Fig (3.3) will be detect.

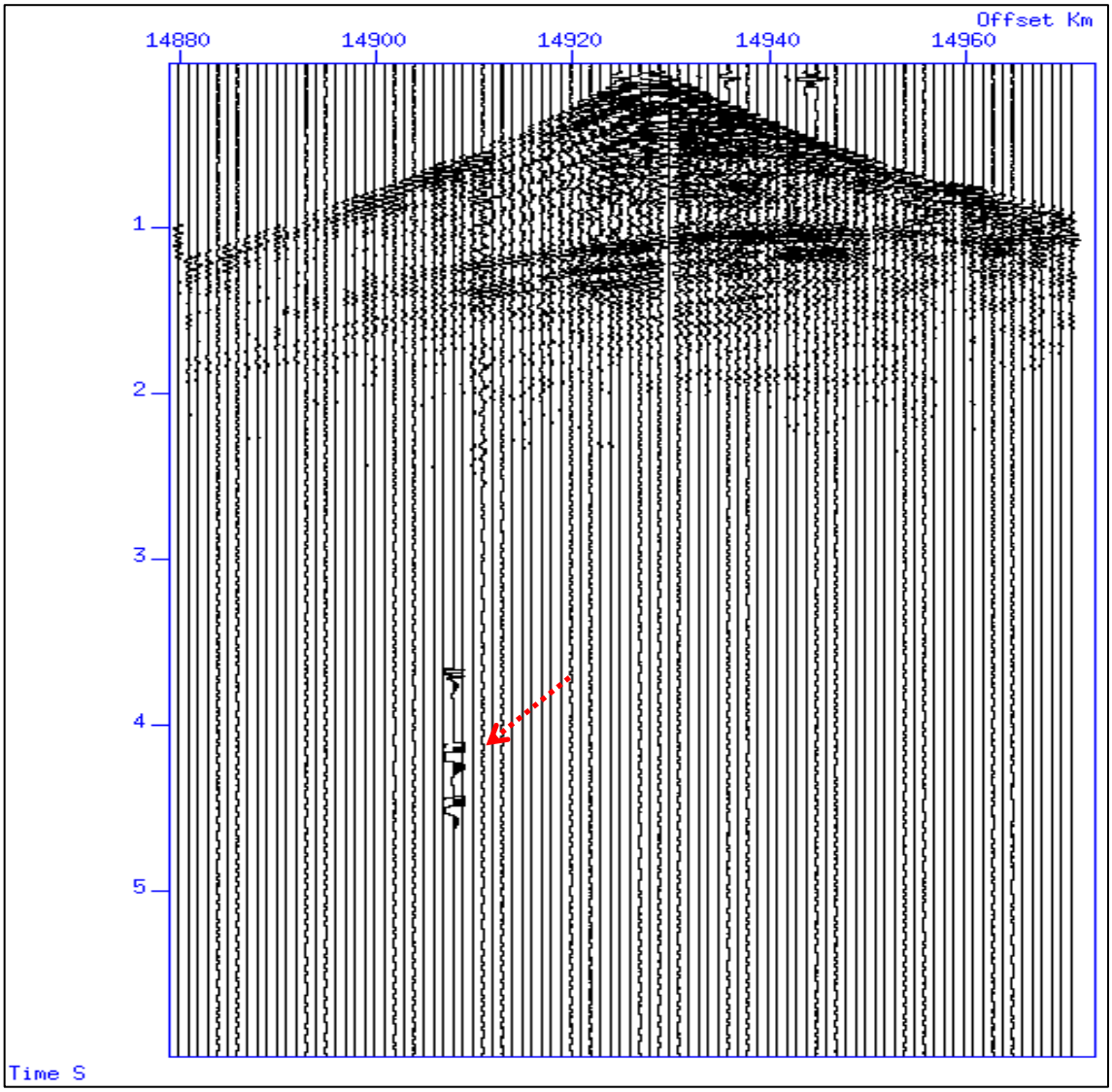


Figure 3.3: Shot with noisy trace as shaded by red arrow.

Two seismic unix applications used for this purpose, which are suwind and sukill. suwind viewing data according to the key word which is available in the headers. The command is:

$ suwind < data.su key=fldr reject=1,2,3,…> data.su

key: key word of the header that data organized according to it.

reject: shots number that should be removed.

After removing the dead shot the next one in the order take its place. The header after this should be re-setup. The sukill used for zeroing noisy trace.

The commend is:

```
$ sukill < data.su key=tracl a=1,2,3,… > data.su
```

key: key word of the header.

a: trace number.

The trace will be without any value but still be accounted just for the order.

3.4 Field Layout

3.4.1 Spread types

The spread types is related to the arrangement of geophone groups in relation to the source point (Sheriff, 2002), or to the geometrical pattern of groups of geophones relative to the seismic source. The output from a single shot is recorded simultaneously by the spread during seismic acquisition (Schlumberger, 2017).

The three common types of Spread types (field geometry) is shown in Fig (3.4).

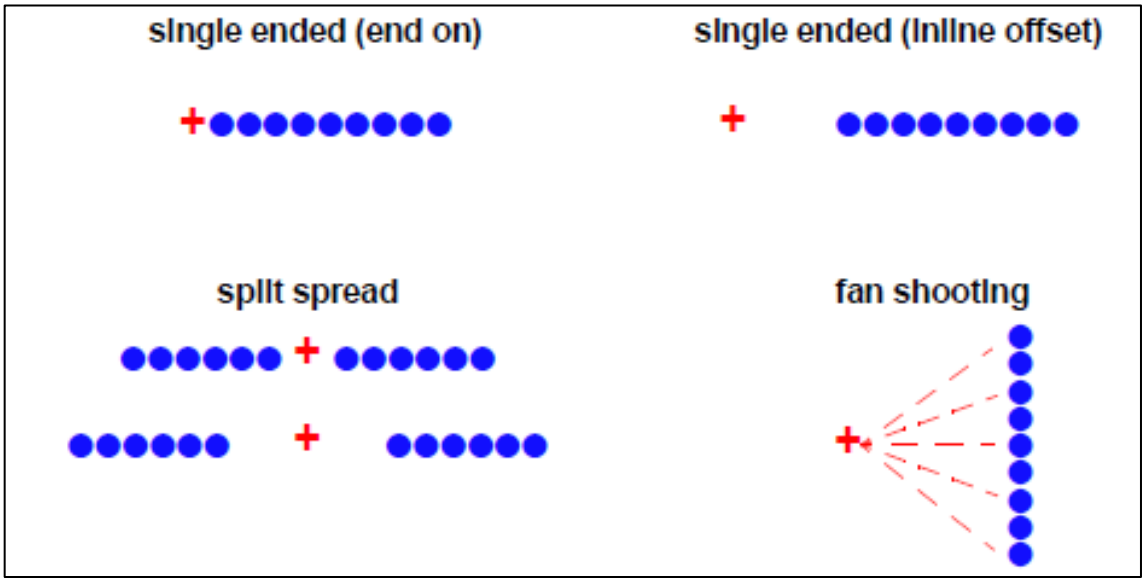


Figure 3.4: Common types of field geometry (Nitsche, 2001).

The seismic source is at one end, and receivers are only on one side of the source it is End on type. For the In-line offset spread, the source is moved away

from the nearest receiver because the seismic energy level may be high enough for useful recording by nearby geophones. Split spread or Straddle spread has been the most commonly used spread before the coming into operation of digital recording. In this case, the source is at the center and geophones are symmetrically placed on either side of it. Geophones may be offset with respect to the source when so desired. Records from a split spread reflection survey are used to detect the dipping reflectors and to find the amount of slope. The detection points receivers are laid out in fan-like arrays at distances from a common source point. This spread called Fan shooting.

3.4.2 CDP recording and gathers type

In multichannel seismic acquisition where beds do not dip, the common reflection point at depth on a reflector, or the halfway point when a wave travels from a source to a reflector to a receiver. In the case of flat layers, the common depth point is vertically below the common midpoint. In the case of dipping beds, there is no common depth point shared by multiple sources and receivers as in Fig (3.5) (Schlumberger, 2017).

A recording processing method where each source is recorded at a number of geophone locations and each geophone location is used to record from a number of source locations. After correcting these data for statics, normal moveout, and DMO since dipping reflections do not involve a common reflecting point they are combined stacked to provide a common-midpoint section that approximates the traces that would be recorded by a coincident source and receiver at each location, but with improved discrimination against noise. The objective is to attenuate random effects and events whose dependence on offset is different from that of primary reflections (Sheriff, 2002).

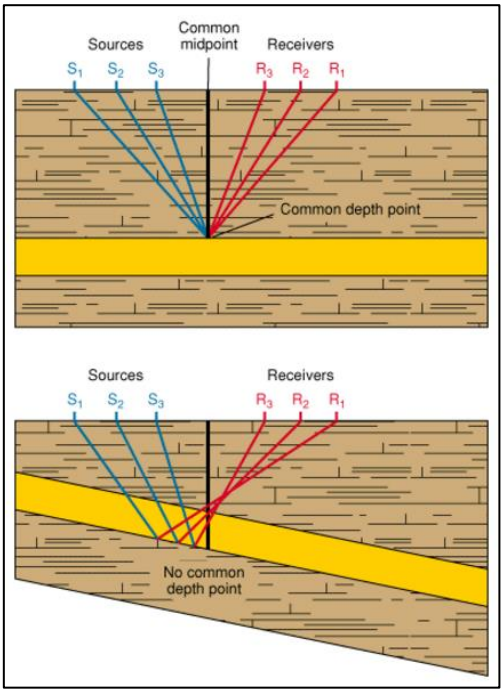


Figure 3.5: Common depth point (Schlumberger, 2017).

As a result the seismic traces can be viewed in different gathers. A gather is a collection of seismic traces which share some common geometric attribute which are sorted from field records. These gathers used in processing or as QC (Quality Control) for the processing steeps. These gather are :

- Common source or receiver gathers basic quality assessment tools in field acquisition. When the traces of the gather come from a single shot and many receivers, it is called a common shot gather Fig (3.6) left. A single receiver with many shots is called a common receiver gather Fig (3.6) right. It is very easy to inspect traces in these displays for bad receivers or bad shots (Schlumberger, 2017).

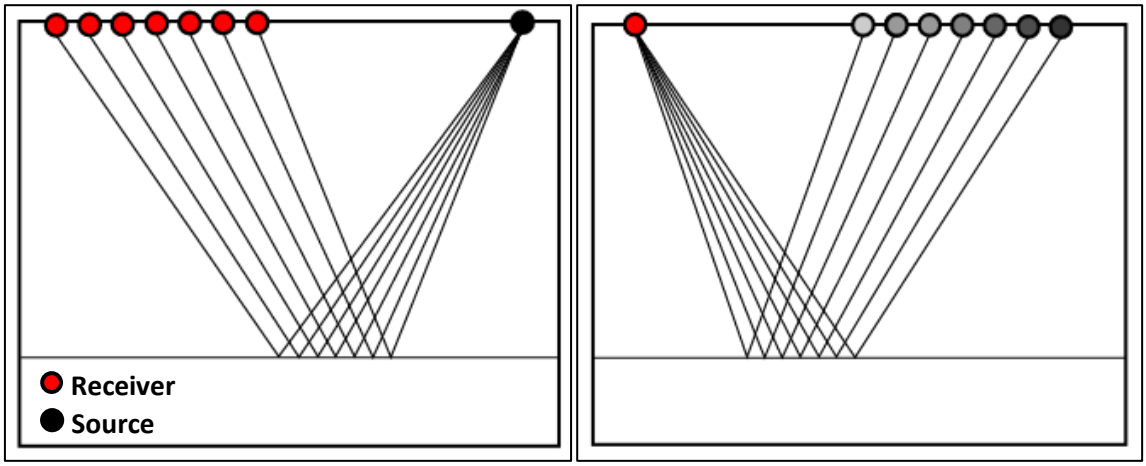


Figure 3.6: Common source and receiver gather (Schlumberger, 2017).

- Common midpoint gather the stereotypical gather traces or sorted by surface geometry to approximate a single reflection point in the earth. Data from several shots and receivers are combined into a single gather. The traces are sorted by offset in order to perform velocity analysis for data processing and hyperbolic moveout correction. Only shot–receiver geometry is required to construct this type of gather Fig (3.7) (Schlumberger, 2017).

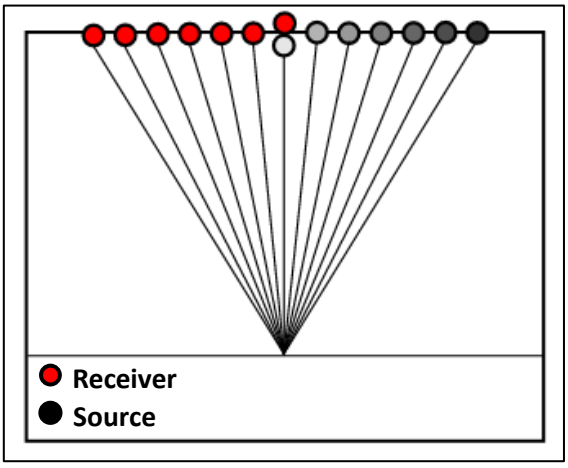


Figure 3.7: Common midpoint gather (Schlumberger, 2017).

- Common offset gather used for basic quality control, because it approximates a structural section. Since all the traces are at the same offset, it is also sometimes used in AVO analysis; one can quickly inspect the approximate spatial extent of a candidate AVO anomaly. If the near

offset trace is used for each shot, this is called a brute stack Fig (3.8). (Schlumberger, 2017).

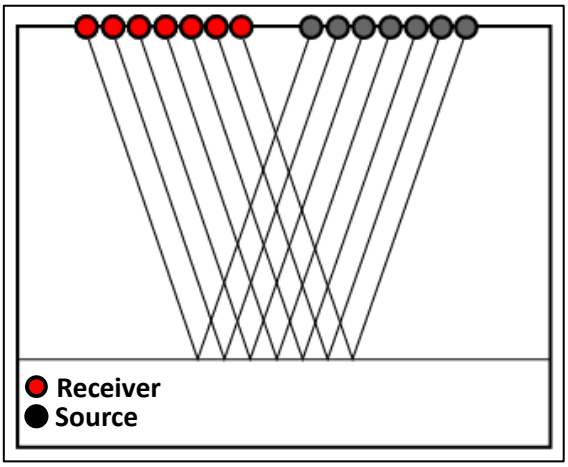


Figure 3.8: Common offset gather (Schlumberger, 2017).

3.4.3 Geometry Defining

Geometry information tells us how the Multiple Coverage was achieved by defining the coordinates of shot and receivers relationship between file numbers and shot locations, relationship between shots and receivers, missing shots and or receivers and attributes for shots and receivers e.g. elevations, depths etc (Westren geco, 2007).

As mention before that the ebcdic and binary real headers are not preserved in the su format. It have just the trace header which should contain the geometry information.

After the conversion from segy to su format the minimum amount of information that existed in trace header as in Fig (3.9) are tracl trace sequence number within line, tracr trace sequence number within real and tracf trace number within field record these which will be used to calculate geometry.
At first the source and receiver position will be added in order to do that the survey information will take in account. The shot point interval, receiver interval, spread type and roll on.

```
tracl=1 tracr=1 fldr=1 tracf=1 trid=1 ns=3000
dt=2000
tracl=2 tracr=2 fldr=1 tracf=2 trid=1 ns=3000
dt=2000
tracl=3 tracr=3 fldr=1 tracf=3 trid=1 ns=3000
dt=2000
tracl=4 tracr=4 fldr=1 tracf=4 trid=1 ns=3000
dt=2000
tracl=5 tracr=5 fldr=1 tracf=5 trid=1 ns=3000
dt=2000
tracl=6 tracr=6 fldr=1 tracf=6 trid=1 ns=3000
dt=2000
tracl=7 tracr=7 fldr=1 tracf=7 trid=1 ns=3000
dt=2000
tracl=8 tracr=8 fldr=1 tracf=8 trid=1 ns=3000
dt=2000
```

Figure 3.9: Snapshot of traces header file of su data format obtained by seismic unix. The red rectangle represents one trace header.

The geometry calculation start with source coordinates (sx,sy) as in the commands below. Two seismic Unix applications used for this purpose, sushw which is used for set one or more header words using trace number and suchw which is used for calculate header word using one or two header word fields.

After each commands the output data differ from input data because each application added new information. The output data from first command will be input to the next command and so on. The first input data data1.su and median data (data1.su, data2.su, data3.su) should be deleted at the end of this sequence.

$ sushw < data.su key=sx,sy a=0,0 c=100,0 j=96,96 > data1.su

key: header fields or words.

sx,sy: shot point coordinate.

a: represent the first values of sx and sy for the first trace of the first shot.

c: shots increment (shot point interval).

j: number of traces in the one shot.

The sushw application will numbering the 96 trace of the first shot with (0,0) after finishing the first shot the second shot will be numbered with (100,0) and so on until the end. In each numbering cycle the sy coordinate stay zero because the survey area with small slopes not effective. The sx coordinate after each

numbering cycle will be shifted 100m which is equal to shot point interval until the last shot in the survey. After this step the output of it will be the input for the next so the receiver coordinates defined.

```
$ sushw < data1.su kay=gx,gy a=-2375,0 b=50,0 c=50,0 j=96,96
> data2.su
```

gx,gy: receiver coordinates.

b: traces increment within shot (1,2,3,…96).

The first numbering value of gx=-2375m for the far offset geophone of symmetry split spread which decrees 50m each time which is receiver interval until near offset geophone equal to -25m then to the right of spread start at near offset 25m to far offset 2375m. In this numbering manner all geophone of each shot will be numbered. The new geophones group of the next shot the gx value will start at -2325 and end at 2325 this pattern controlled by the c value at the above commend which is represent the roll on of the field. The input data was data1.su which only (sx,sy) was defined while the output data data2.su with both (sx,sy) and (gx,gy) were defined at the end of this step which will be redirected to step three as input.

```
$ sushw < data2.su kay=offset a=-2375 b=50 j=96 > data3.su
```

In this step the offset will be defined the c value which represent the roll on will be canceled because the offset value (a value) fixed in each shot. The output data (data3.su) will have (sx,sy), (gx,gy) and offset are defined and then will be redirected to the last step to define the CDP (common depth point).

```
$ suchw < data3.su kay1=cdp kay2=gx kay3=sx a=2425 b=1 c=1 d=50
> data4.su
```

d: trace number shift.

The suchw application calculates the CDP according to the equation 3.1 (Forel et al, 2005):

$$key1 = (a + b*key2 + c*key3) / d \quad (3.1)$$

The d value use to normalize the values computed in the numerator so cdp values increment simply (Forel et al, 2005). The a value represent the first cdp for far offset geophone which calculation start at it. At this end the geometry definition completes.

3.5 Amplitude Recovery

The amplitude recovery is adjusted to seismic data to compensate for attenuation, spherical divergence and other effects. The goal is to get the data to a state where the reflection amplitudes relate directly to the change in rock properties giving rise to them (Schlumberger glossary, 2017).

The normal procedure is recovery the amplitudes of samples, traces and shots. With regard to equalizing amplitudes on one trace, it may be obvious that reflection late in the section will be of a much smaller as in Fig (3.10) in amplitude than the ones early in the section, simply due to energy losses in the subsurface.

The most important energy losses are due to geometrical spreading, absorption of the rocks and transmission losses. Geometrical spreading is spreading of the wavefront since the energy of a wave is inversely proportional to $1/r^2$ (in a homogeneous medium). This means that the amplitude is decaying as $\frac{1}{r}$. Although the measured field is from a correct physical experiment, some aspects cannot be dealt with in standard processing. Therefore, corrections are made for the raw data to match with the assumptions in further data processing. The first assumption is that the data is processed as if it was measured in a two-dimensional world, which means a spreading which is proportional to $1/\sqrt{r}$ for the amplitude. A correction is made on the traces with a spreading function. This geometrical spreading function is specified as a traveltime and a specific average velocity function (Drijkoningen and Verschuur, 2003).

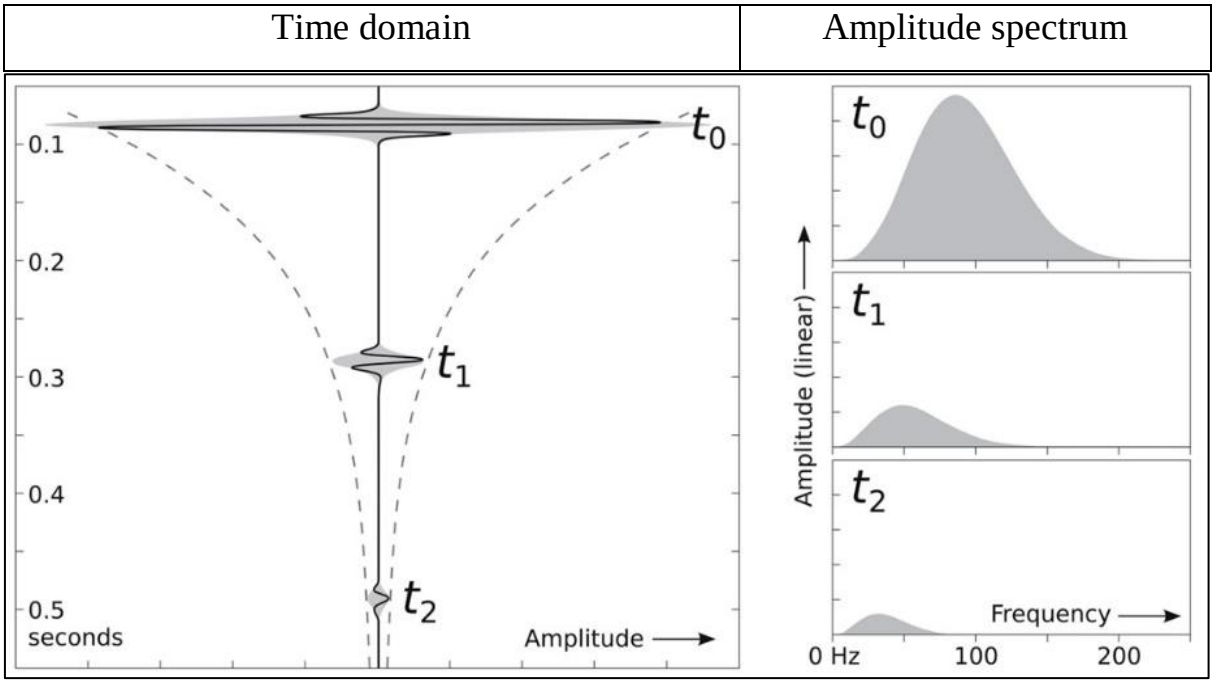


Figure 3.10: Amplitude decay (Reine, 2013).

The other (gain) correction is applied to correct for absorption, and this one is corrected with an exponential gain function, where the factor in the exponential is related to the average absorption coefficient of the rocks. Then, the last correction is to confront the transmission losses at interfaces in the subsurface although, this correction is usually included in the exponential gain for the absorption losses (Drijkoningen and Verschuur, 2003).

In the seismic unix the sugain application used to do various types of gain.

```
$ sugain < data.su tpow=1 epow=0.5 > data.su
```

tpow: multiply data by t^tpow.

epow: multiply data by exp(epow*t).

the tpow option used to compensate amplitude decay which result from spherical divergence and epow option used to compensate amplitude losses which result from absorption.

3.6 Seismic noise

Noise is any disturbance on the seismic record which tends to obscure primary reflections from rock strata. It may be conveniently divided into two sorts random noise and coherent (Ashcroft, 2011).

Coherent noise is generated by the shot itself. S waves, Love and Rayleigh waves (ground roll) and reflections from surface irregularities are all forms of coherent noise. In shallow refraction work these slow, and therefore late arriving, waves usually prevent the use of any event other than the first arrival of energy (Milsom, 2003).

Coherent noise exist in an organized form from trace to trace and yet they contain no geologic information. Coherent noise in the form of surface wave which exhibit strong coherency and essentially obscure the entire desired primary reflection. Source generated noises noticed in seismic records are ground roll, direct rays, ghost reflections, and multiple reflections Fig (3.11) (Onajite, 2014).

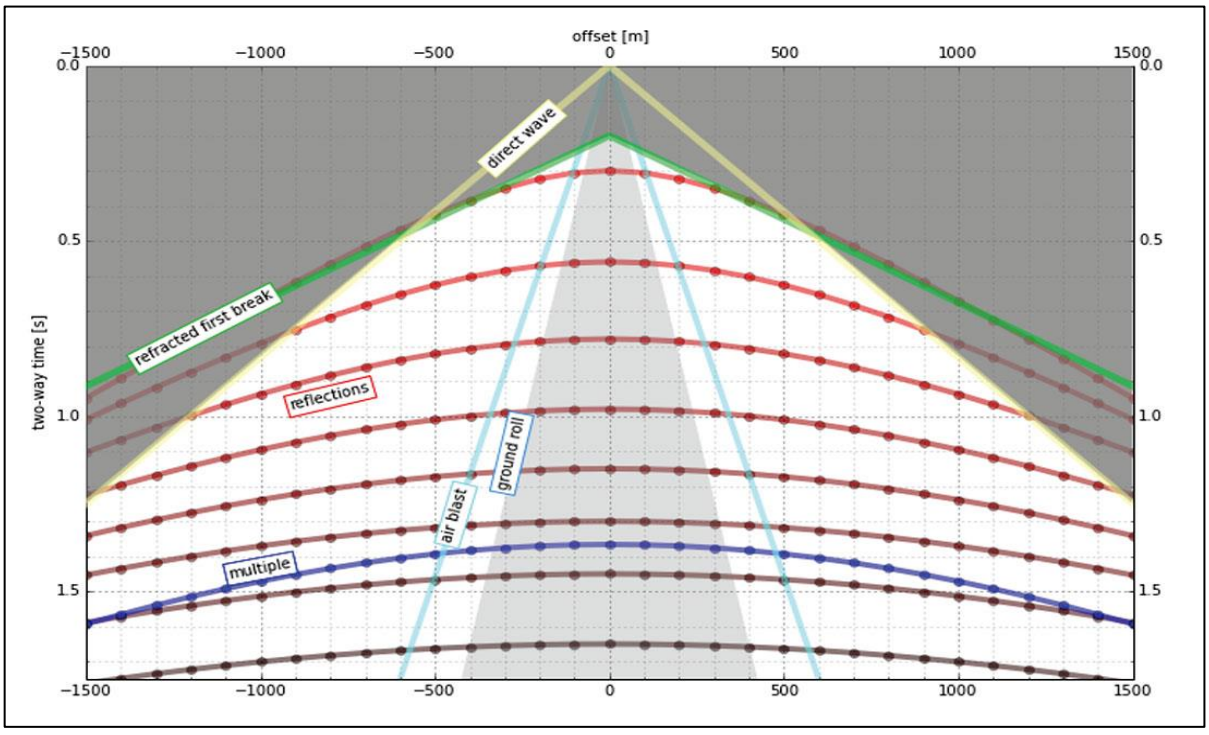


Figure 3.11: Seismic noise type (Bianco, 2014).

Random noise is noise generated by activities in the environment where seismic acquisition work is being carried out. Movements of traffic, animals and people all generate random noise and can, to varying extents, be controlled. It should at least be possible to prevent the survey team contributing, by giving warning using a whistle or hooter (Milsom, 2003).

This noise appears in a seismic record as spikes. In a marine acquisition, random noise can be created by ship props, drilling, other seismic boats, and wind or tidal waves. Radom noises in seismic data are recognized principally by the absence of coherency or continuity from one seismic trace to the next. Note that coherent noise is consistent from trace to trace. Random noise can be reduced or removed from data by stacking the traces, filtering during processing or using arrays of geophones during acquisition (Onajite, 2014).

3.7 Seismic Noise Filtering

3.7.1 Frequency Filter

Frequency Filter Permit filtering in accord with arbitrarily chosen characteristics that might prove difficult or impossible to achieve with physical circuit components (Sheriff, 2002). Digital filter takes the form of an arithmetical operation carried out on the string of numbers that represents the signal (Ashcroft, 2011).

In order to separate noise from useful reflected signal, criteria of their frequency range and velocity may be utilized. If the low frequency, high energy noise, such as surface waves, has frequencies which are well separated from reflection signal frequencies, they may be filtered out during initial recording itself. However, it is found that noise spectrum often overlaps the signal spectrum, and for this reason the frequency filtering is of limited value only (Upadhyay, 2004).

The filter response may be expressed either in the time domain or in the frequency domain. If the response is known in one domain it is possible to

express it in the other domain. For accomplishing the filter operation, both the seismic signal and filter response characteristics should be expressed in the common domain, either in the time domain or in the frequency domain (Upadhyay, 2004).

There are many varieties of filters. As in Fig (3.12).

a) Low cut off filter: A low cut off (high pass) filter applied to a seismic trace attenuate frequencies less than the cut off frequency.

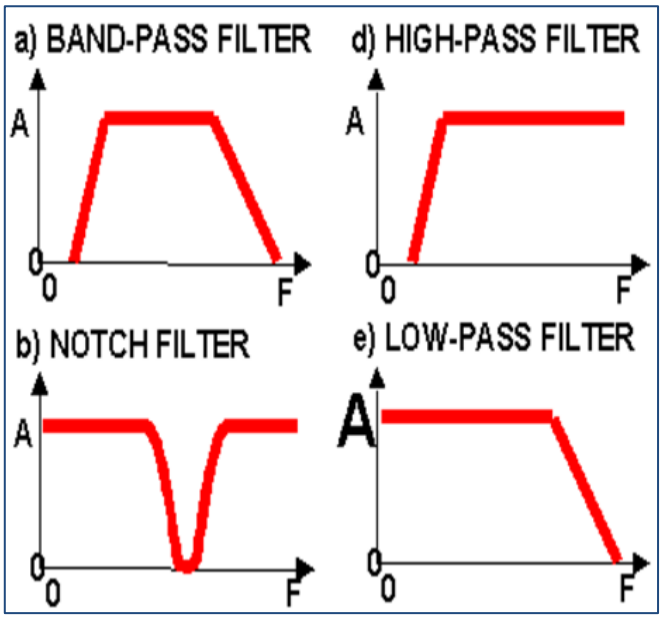


Figure 3.12: Frequency filter types (Basic Definitions, 2013).

b) High cut off filter: A high cut off (low pass) filter applied to a seismic trace attenuate frequencies above the cut off to make the output more low frequency. The high cut off filter is very important as it prevent aliasing.

d) Band pass filter: a band pass filter rejects frequencies below its low cut off frequency and above its high cut off frequency while passes a range of frequencies within the acceptable limits of the filter unaltered.

e) Notch filters: sharply reject a very narrow band of frequencies.

In order to design band pass filter for the data that I have, it should be transformed to the frequency domain. In the frequency domain the frequency content be obvious so the frequency corner of filter is chosen Fig (3.13).

The seismic unix have an application used for the domain transformation which is suspecfx. The suspecfx application will be used with another application in same commend to overlap all seismic traces in one averaged amplitude spectrum.

```
$ suspecfk < data.su | sustack key=dt | suxwigb style=normal &
```

suspecfk: the time-frequency transform application.

sustack: stack traces with chosen key (parameter).

dt: sample interval in micro seconds.

suxwigb: wiggle trace viewer.

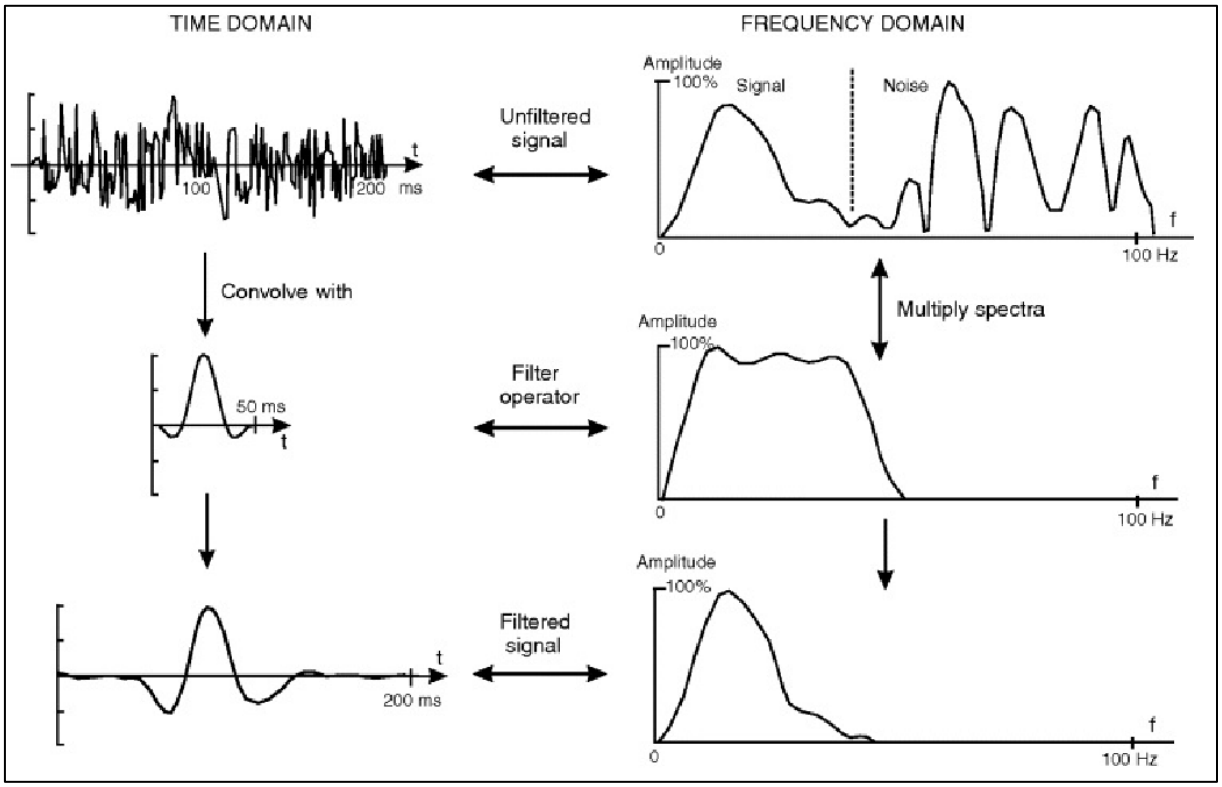


Figure 3.13: Filtering in time and in frequency domain (Ashcroft, 2011).

style: one of suxwigb options that controls on display plane vertical or horizontal . normal mean horizontal.

After viewing the amplitude spectrum of the data the frequency corners is chosen. The sufilter application used for filtering.

& sufilter < data.su f=10,15,45,50 > data.su

f: it mean the boxcar frequency.

3.7.2 Dip filter

An F–K filter is designed to suppress unwanted events in the frequency-wavenumber (F–K) domain. When applying multidimensional Fourier transforms, such as from (t, x) to (f,k_x), linear events in the original domain will also be linear events in the transformed domain, except that the orientations of each event in the two domains are perpendicular to each other Fig (3.14) (Chun & Jacewitz, 1981). If there are linear noises, or if there are noises with dip (offset or time) less than a certain angle, such as ground rolls, we can mute such noise in the F–K domain, and then transfer the remaining data back to the t–x domain. Hence F–K filtering is also called dip-filtering when it is used to remove linear events of certain dip angle (Zhou, 2014).

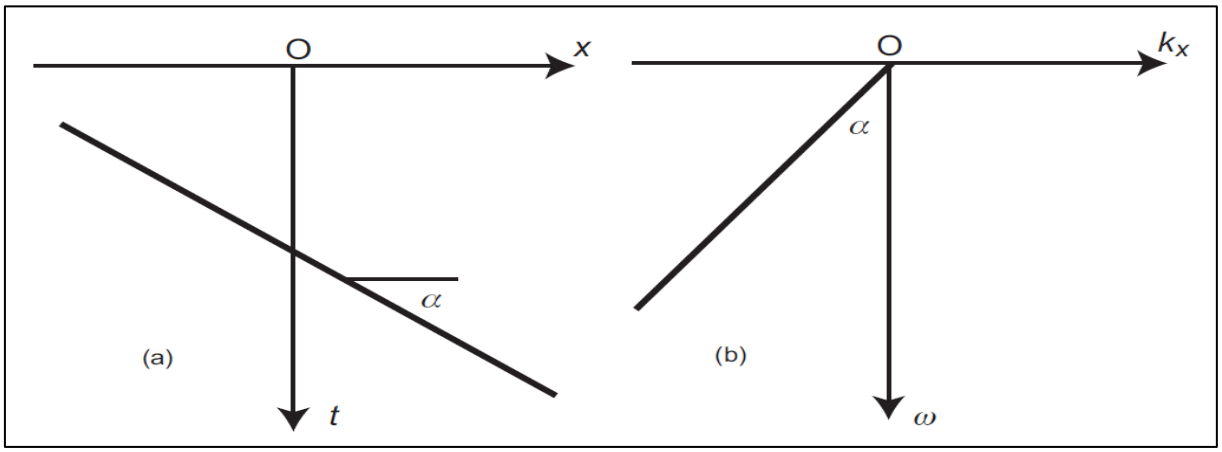


Figure 3.14 : Linear events and their orientation before and after 2D Fourier transform (a) in time domain before transformation (b) in wavenumber domain after transformation (Zhou, 2014).

The attenuation of multiples based on velocity discrimination between primaries and multiples in the F-K domain. Apparent velocities differing significantly from those of the reflection events characterize linear coherent noise. Such noise can therefore be attenuated by muting in the F-K domain. Filtering is based on defining a rejection zone Fig (3.15) corresponding to unwanted energy (or apparent velocities) (Yilmaz, 2001).

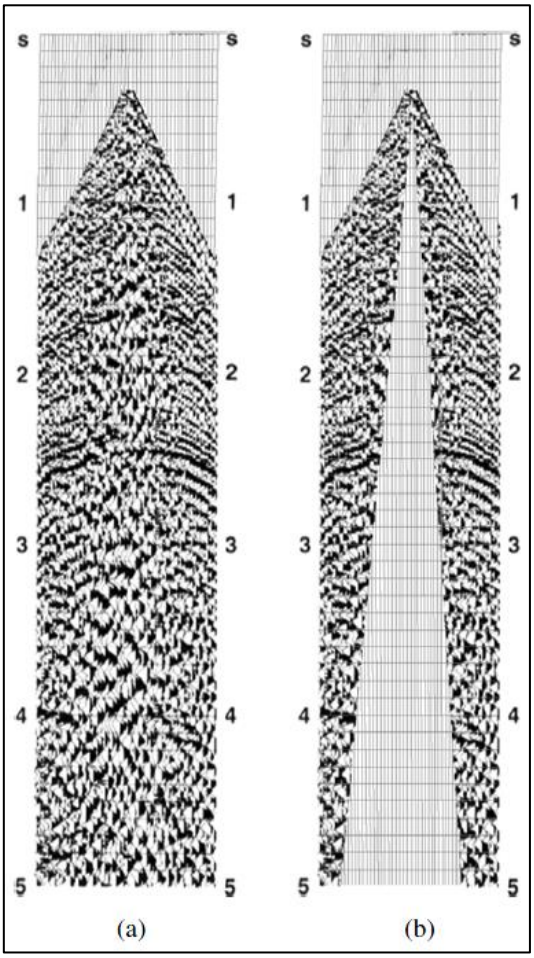


Figure 3.15: (a) Raw shot (b) F-K data filtered (modified from Gadallah and Fisher, 2009).

The rejection zone must be neither too wide so that it suppresses signal contributions in the pass zone nor too narrow. Hence, there must be a smooth transition from the reject zone to the pass zones (i.e. tapering of edges).

F-K filtering fails when the apparent velocity range defining the noise significantly overlaps those governed by the reflection or when the noise mode exhibits a large amount of dispersion(Yilmaz, 2001).

The sudipfilt application used for filtering the data.

```
$ sudipfilt < data.su dt=1 dx=1 slopes=-14,-7,7,14 amps=0,1,1,0 &
```

dt: time sample interval.

dx: geophone spacing.

slopes: slope of noise.

amps: the rejection option.

In this command the geophone spacing and time sample interval were chose equal 1 (dx/dt=1) in order to avoiding small slope values (Seismic unix Self-Documentations, 2008).

3.8 Muting

Muting is the process of excluding parts of the traces that contain only noise or more noise than signal as shown in Fig (3.18).

The far geophone groups are quite distant from the energy source. On the traces from these receivers, refractions may cross and mixed with reflection information from shallow reflectors. However, the nearer traces are not so affected.

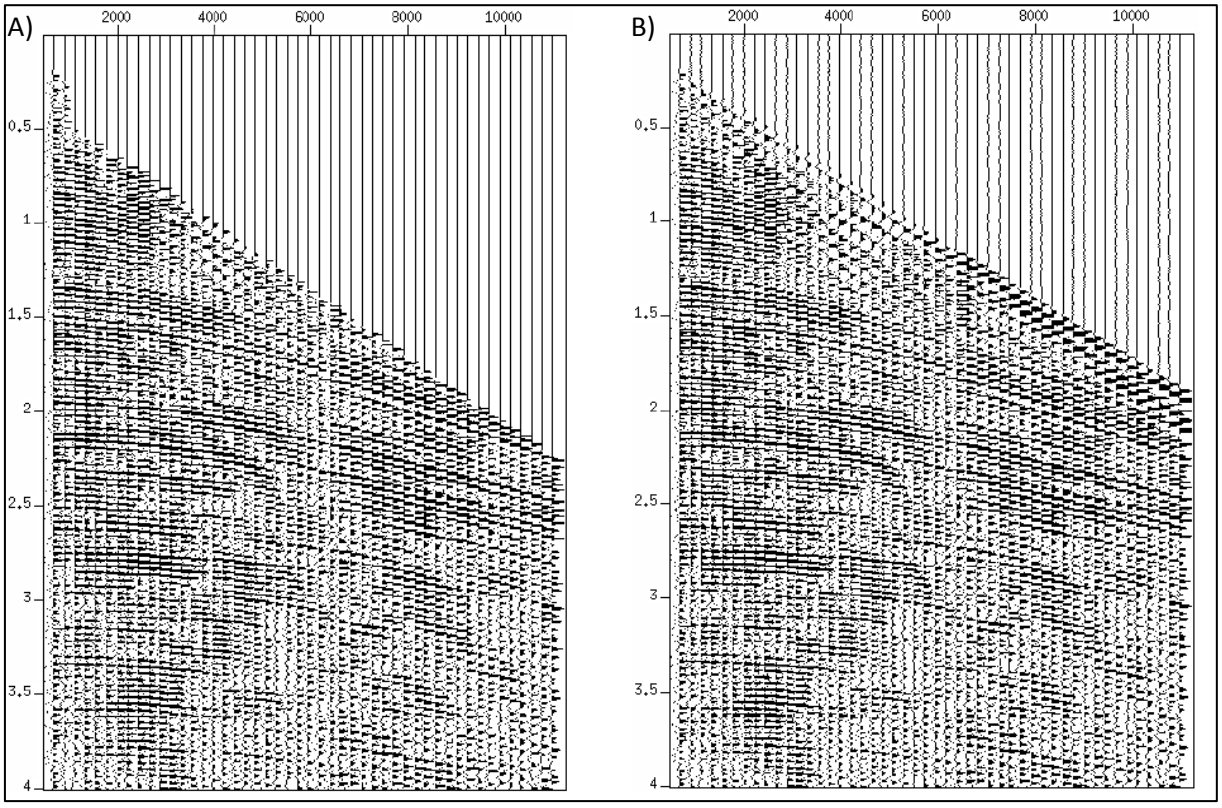


Figure 3.18: Two seismic sections. A) on the left side after using mute, B) on the right without mute (Forel et al, 2005).

When the data are stacked, the far traces are muted (zeroed) down to a time at which reflections are free of refractions. The mute schedule is a set of time, trace pairs that define the end of the muting. Mute changes the relative contribution of the components of the stack as a function of record time. In the early part of the record, the long offset may be muted from the stack because the first arrivals are disturbed by refraction arrivals, or because of the change in their frequency content after applying normal moveout The transition where the long offsets begin to contribute may be either gradual or abrupt (Gadallah and Fisher, 2009).

sumute used to mute the data and all noises in traces before first arrive.

$ sumute < data.su tmute=1.20978,0.0318364,1.15338 xmute=1,48,96 key=tracf mode=0 &

tmute: time at which reflections are free of refractions.

xmute: guiding the mute by traces.

key: specifying the data type.

mode: specifying mute type.

The tmute values selected according the visual examination of shot gather using the suxwigb feature that read the x,y coordinate of the pointer (mouse).

3.9 Deconvolution

Deconvolution is process designed to enhance the vertical resolution of the seismic data by attenuating the undesirable signals such as short period multiples. It is also called inverse filtering (Sheriff, 2002).

3.9.1 Autocorrelation

The auto-correlation function (ACF) or autocorrelogram is simply the cross-correlation of a signal with itself. The peak value will occur when mutual shift is zero and all peaks and troughs as in Fig (3.16) cross multiply to give positive numbers. If you try scanning a signal past itself, you will appreciate that the ACF will be symmetrical about the position of coincidence (maximum ACF), no matter what the shape of the signal is (Ashcroft, 2011).

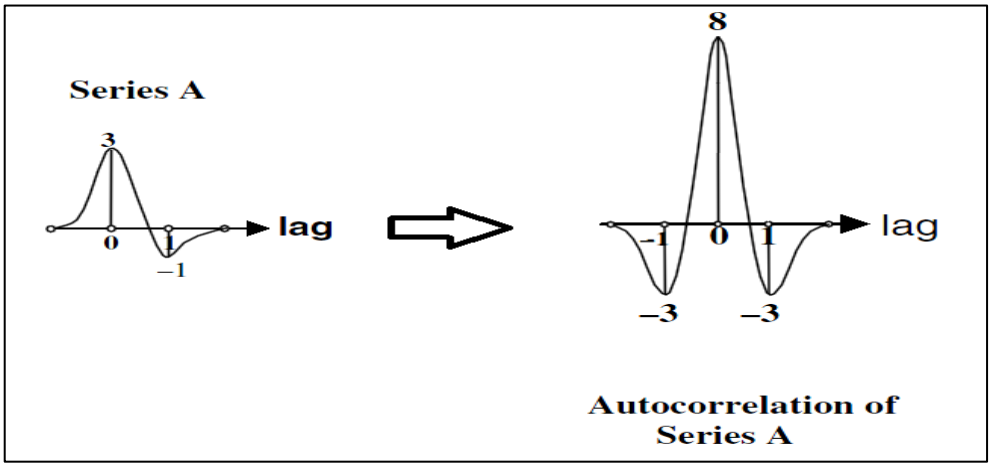


Figure 3.16: The autocorrelation (modified from Gadallah and Fisher, 2009).

For that reason, the ACF is normally shown one-sided, plotted from the central peak, the point of coincidence at shift equal zero. The amplitude at zero shift represents the sum of the squares of all the signal samples, i.e. the energy of the waveform (Ashcroft, 2011).

The ACF is widely applied in processing to assess the amount of reverberation that is present in a waveform. When present, reverberation will give rise to large values in amplitude at some value of shift other than around zero shift. Short-term reverberation will give rise to a short oscillatory tail in the central waveform of the ACF beyond the second crossing of the time axis. Long-period reverberation will give rise to high values later in the ACF (Ashcroft, 2011).

```
$ suacor < data.su ntout=1001 sym=0 > data.su &
```

suacor: autocorrelation application.

ntout: time sample number.

sym: display one side of signal or the two sides.

The suacor used for choosing the parameters of the next step which is the predictive deconvolution.

3.9.2 Predictive Deconvolution

Use of information from the earlier part of a seismic trace to predict and deconvolve the latter part of that trace. Some types of systematic noise, such as reverberations and multiples Fig (3.17) can be predicted. The difference between the predicted value and the actual value is called the prediction error it is sensitive to new information such as primary reflections. Predictive deconvolution may also be used in a multitrace sense, where one tries to predict a trace from neighboring traces (Sheriff, 2002).

The effect of the operator may be visualized in terms of convolution by scanning the lead spike of the operator scans the early part of the waveform and reproduces it unaltered for n sample intervals. From then on, the reverberant tail generated by the lead spike of the operator is cancelled by the rest of the operator as it works progressively over the whole of the waveform.

The word prediction is used because the filter's tail, as it scans the early part of the waveform predicts what the reverberation is going to be and subtracts it from the reverberant waveform generated simultaneously by the lead spike as it traverses the tail of the waveform. If another genuine reflection is lying hidden in the reverberant tail of a waveform, it will not have been predicted and will stand out as a prediction error when the predicted trace is subtracted.

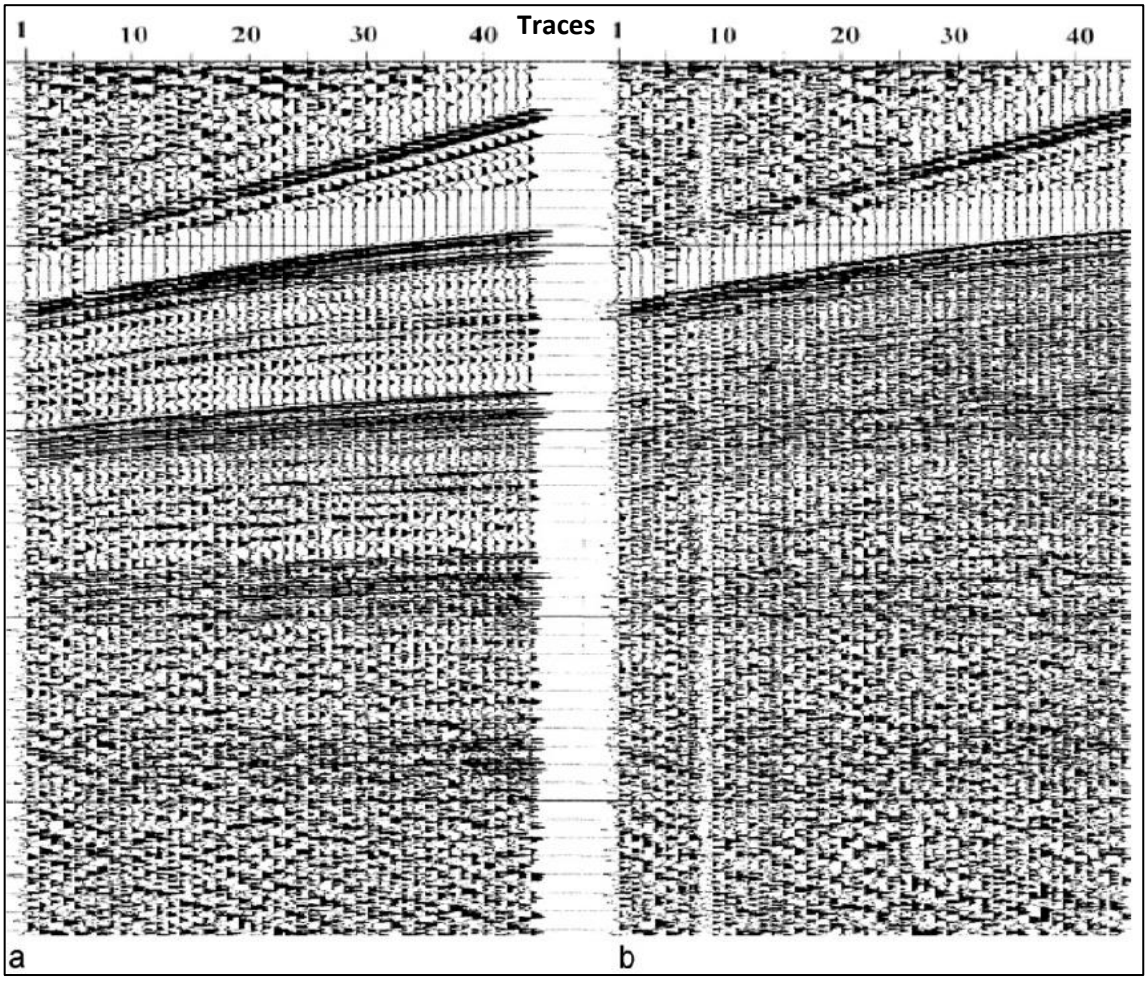


Figure 3.17: Using predictive deconvolution to eliminate multiples. a: before deconvolution b: after using deconvolution (Onajite, 2014).

In designing the operator, the prediction distance, *n*, is generally taken as the second zero-line crossing point on the ACF, which marks the time extent of the basic wavelet. The length of the operator is chosen to extend over the length of the reverberant tail of the ACF. Prediction distance and length of operator are key processing parameters that you will commonly see listed on the labels of time-sections. Note that the shape of the basic wavelet is not affected by this type of deconvolution Fig (3.17) (Ashcroft, 2011).

The supef is the application that used to do deconvolution in seismic unix.

Supef < data.su minlag=0.048 maxlag=0.576 > data.su &

minlag=first lag of prediction filter.

maxlag= last lag of prediction filter.

3.10 Sorting

Seismic data acquisition with multifold coverage is done in shot receiver coordinates. Seismic data processing, on the other hand, conventionally is done in midpoint offset coordinates. The required coordinate transformation is achieved by sorting the data into CMP gathers. Based on the field geometry information, each individual trace is assigned to the midpoint between the shot and receiver locations associated with that trace. Those traces with the same midpoint location are grouped together, making up a CMP gather (Yilmaz, 2001). In seismic unix package the susort is an application used to do the sorting in all possible coordinates that exist as in Fig (3.18).

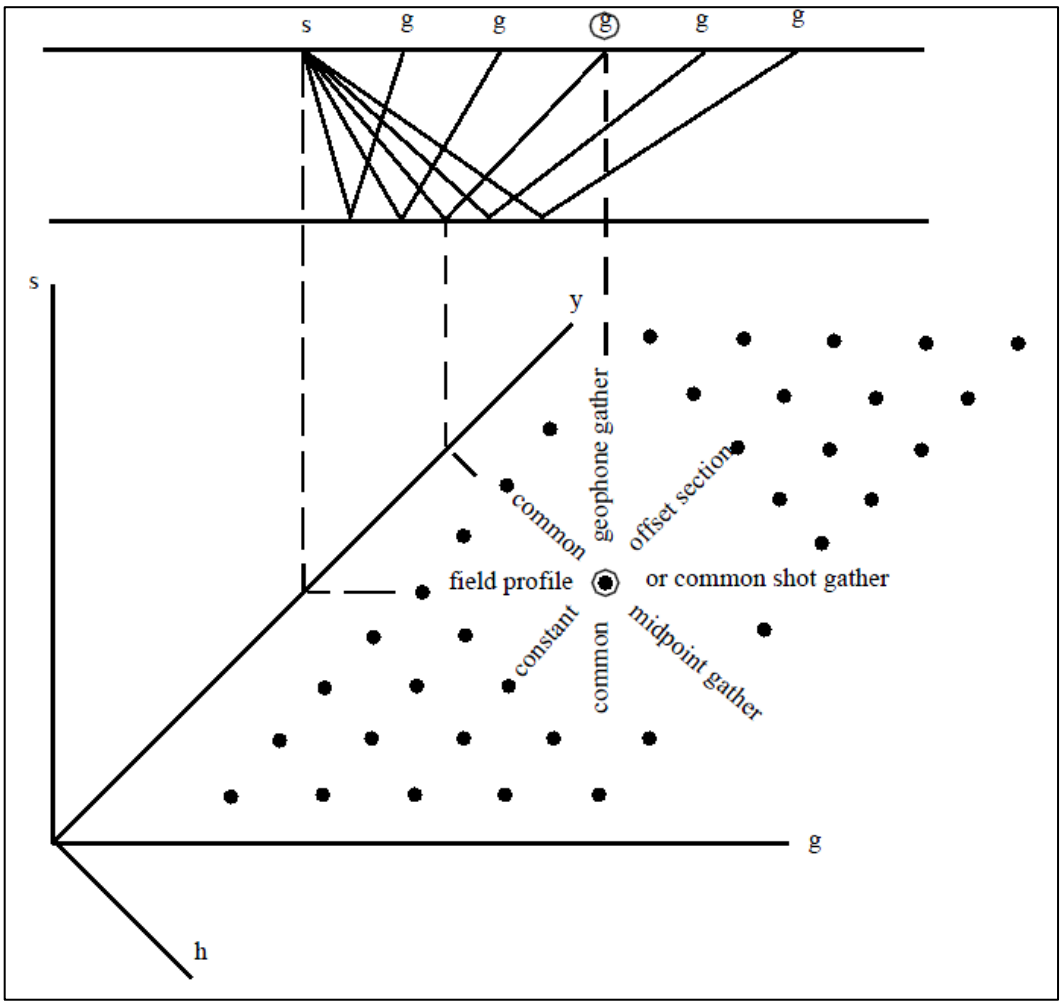


Figure 3.18: The various sorting types. seismograms from a shot at location(s) to geophones at locations labeled g. The lower diagram is called a stacking diagram. Each dot in this plane depicts a possible seismogram (trace). Think of time axis running out from the plane (Claerbout, 2010).

$ susort < data.su > data.su cdp offset &

cdp: common depth point coordinate.

offset: offset coordinate.

There are two coordinates in this command to sort traces by cdp gather and within each gather by offset with both sorts in ascending order (Seismic unix Self-Documentations, 2008).

3.11 Velocity Analysis

Velocity analysis is the process whereby the velocity that flattens the reflection hyperbola on a CMP/CDP gather is determined. The velocity is called the stacking velocity. In velocity analysis, velocities are picked at selected locations along the seismic section and the results are linearly interpolated from one analysis location to the other as long as the picks are from the same reflector and the same reflection time (Onajite, 2014).

Seismic velocity plays an important role in all activities involved in seismic exploration surveying. Its importance stems from the fact that the end product of any seismic survey is a time-image of the subsurface geology. Thus, to convert the time-image data into depth domain, velocity must be made available.

In seismic reflection surveying, velocity computations, aim at finding the seismic velocity expressed as function of depth. There are several ways to compute the seismic velocity function. Velocity computations are made either by methods based on borehole data or by methods based on analysis of seismic data (Al-sadi, 2017).

Spread length is important factor in deriving good stacking velocity values. The longer the spread, as long as it does not exceed depth to target, the better the NMO values and therefore the better the discrimination between primary and multiple reflections. Depending on the record quality in an area, the fold can affect the signal to-noise ratio, as the higher the multiplicity the better random noise attenuation. The details of the shallow events on the seismic section are as important as the target zone and can contain a very valuable information that affect the fidelity of a prospect. Therefore, front end muting is very crucial in eliminating noise trains such as body waves. Care must be taken in selecting the mute and protecting (not muting) as many short traces (close to the source) in order to enhance the coherency of the shallow reflections. If a coherent noise pattern, such as surface waves and airwaves, cannot be attenuated effectively by

digital filter application (frequency of the noise is the same as a primary) a surgical mute can be used to eliminate the noise train and accordingly, obtain a better velocity analysis (Gadallah and Fisher, 2009).

Resolution of the velocity estimates depends on the time gate length (normally 20ms) over which the normal moveout calculations are made, the velocity increment and the velocity range. Both factors affect the resolution of the estimates and the run time on the computer. The frequency content of the data has a great effect of the velocity details especially shallow on the section. It affects the coherency and the lateral and vertical resolution (Gadallah and Fisher, 2009). There are many velocity analysis methods. These are:

- $T^2 - X^2$ Analysis Method.
- Constant Velocity Stack.
- Velocity Spectrum Method.
- Dix's Expanding Spread Technique.
- Seismic Velocity Inversion.
- T − ΔT Method.

In this thesis the velocity spectrum method has been selected.

3.11.1 Velocity Spectrum Method

The initial result of velocity analysis is a set of velocity functions as in Fig (3.19) that are determined at specific CMP locations within the survey. Velocity functions are defined by sets of time, velocity pairs that are picked for significant primary reflections as in Fig (3.20). Linear interpolation between these points defines velocities for every sample in the CMP traces. Spatial interpolation between and extrapolation from these functions establishes a velocity field that defines velocities for every sample in the data volume.

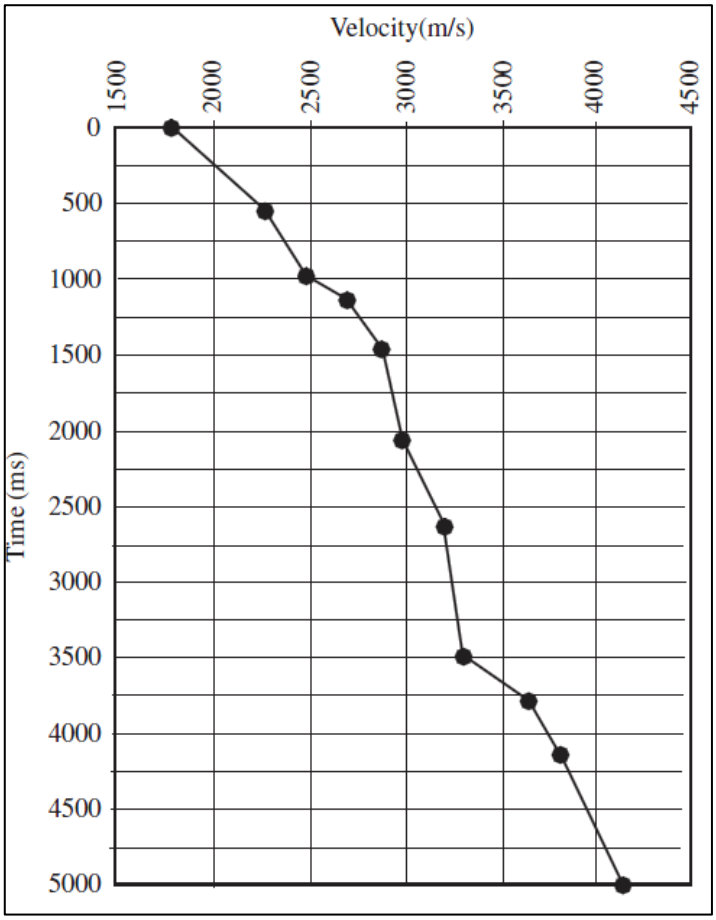


Figure 3.19: Velocity function (Gadallah and Fisher, 2009).

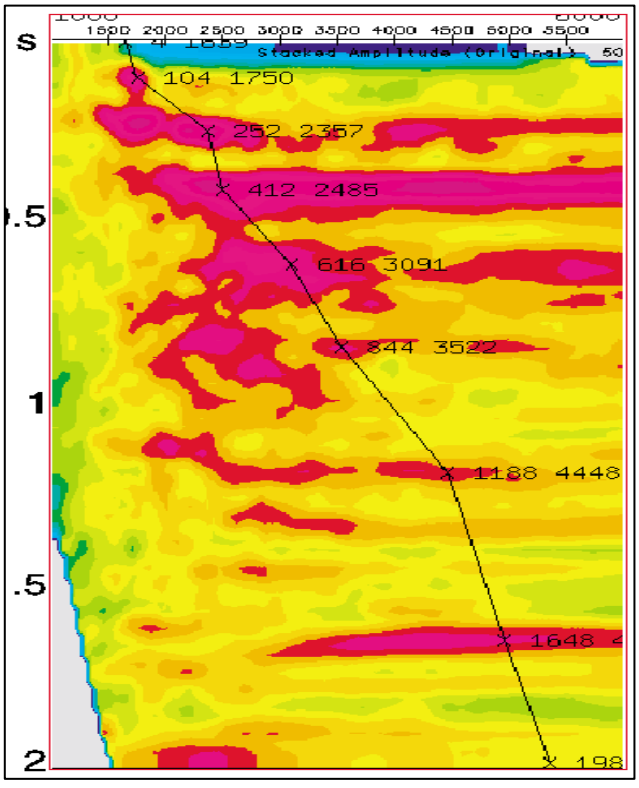


Figure 3.20: Picking velocity of primary reflection (Yilmaz, 2001).

The velocity spectrum method distinguishes the signal along the hyperbola paths even with high random noise level. This is because of the power of cross-correlation in measuring coherency. The accuracy of the velocity spectrum is limited, however, if S/N ratio is poor. The velocity spectrum approach is based on the correlation of the traces in a CMP gather. This method is suitable for data with multiple reflection problems, and less suitable for highly complex structure problems (Gadallah and Fisher, 2009).

In seismic unix package the suvelan application used to compute stacking velocity semblance for cdp gathers.

```
$ suvelan nv=50 fv=1500 dv=50 < data.su | suximage &
```

nv: number of velocities or times that velocity will calculate.

fv: first velocity so the calculation start at it.

dv: velocity sampling interval.

3.12 Normal Moveout Correction (NMO)

The time correction applied to reflection times because of normal moveout. The normal moveout formed because the difference in reflection arrival time which is result from the geophone is not located at the source point. Usually applied to common-midpoint gathers, it is the additional traveltime required because of offset, assuming that the reflecting bed is not dipping and that raypaths are straight lines. this leads to a hyperbolic shape for a reflection as in fig (3.21).

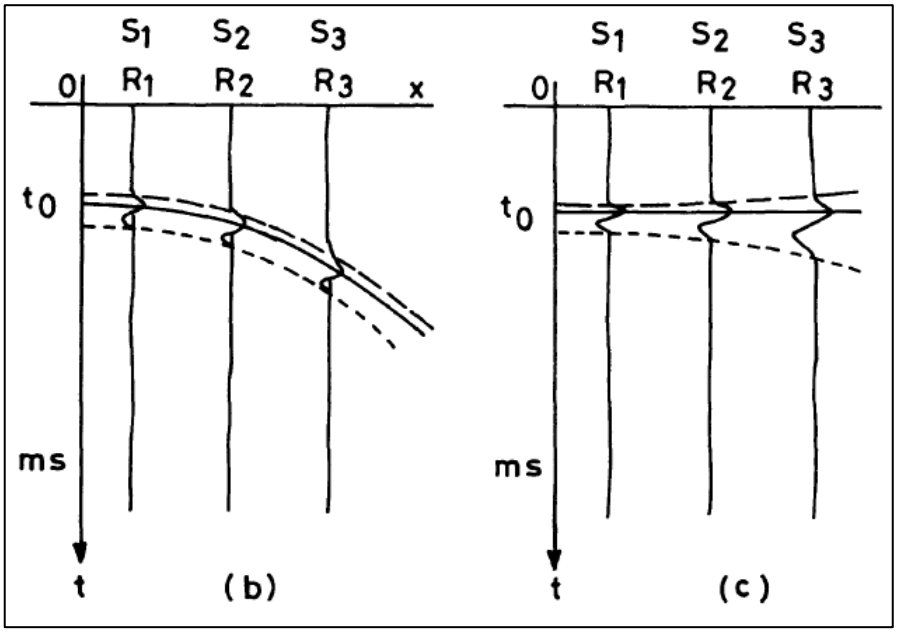


Figure 3.21: Normal moveout correction. b) before correction, c) after correction (Upadhyay, 2004).

Fitting a hyperbola assumes that the actual velocity distribution is equivalent to a constant NMO velocity, but the NMO velocity changes with the offset. However, the assumption often provides an adequate solution for offsets less than the reflector depth (Sheriff, 2002).

3.13 Stack

Generally speaking, trace stacking involves algebraic summing of the sample values (from traces) having common depth point. Usually, the sum is divided by the number of involved traces, to get the mean value instead of the absolute sum. Vertical stacking, involves summing corresponding traces from several shot-records, executed in the same location. This is done normally with weak surface-sources (such as weight dropping and Vibroseis) to get enhanced reflection signals. The sustack application used to stack the seismic data.

```
$ sustack < data.su > data.su &
```

3.14 Ground Penetrating Radar (GPR)

Ground Penetrating Radar (GPR) method is a remote sensing geophysical prospection method that operates on the same principles as the radar equipment used in navigational systems. The transmitter and the receiver are located at the ground surface. The transmitter emits a pulse of electromagnetic (EM) radio waves into the ground. As these EM waves travel through the subsurface, their physical properties and direction of movement are altered as they encounter differences in subsurface materials (Reynolds, 2011).

Any subsurface discontinuity can affect the EM wave, including voids, interfaces between different material types, and localized point sources. Material properties that strongly influence the EM waveform include water content, lithology, density, porosity, and electric/magnetic properties. When EM waves encounter subsurface discontinuities, part of the EM wave is refracted (or bent) and continues to propagate until it is reflected or dissipated, and part of the wave is reflected back to the surface, where it is collected by the receiving antenna (Kearey, et al., 2002)

Data are collected in traces, which represent the total waveform collected at a single surface location. Depth measurements are calculated based on two-way travel time (it is the time for the EM wave to travel from the transmitter to a subsurface discontinuity, then back to the receiver), and the velocity of the EM wave through the subsurface. When travel time is converted to distance and the precise locations of traces are known, images can be produced that detail the shapes, sizes, and depths subsurface features (Reynolds, 2011).

3.15 GPR data acquisition system

GPR systems consist of a pulse generator, an antenna for transmission of electromagnetic pulses, a second antenna for reception of the direct and reflected signals as in Fig (3.22), and receiving electronics to amplify and digitize the

waveforms to be recorded and displayed. In some cases, both antennas are contained in one housing or there is one single antenna with a fast switch for changing between transmission and reception. Timing and triggering of the measurement process is done by a control unit which may also interface to external components like a survey wheel or GPS (Krisch, 2006)

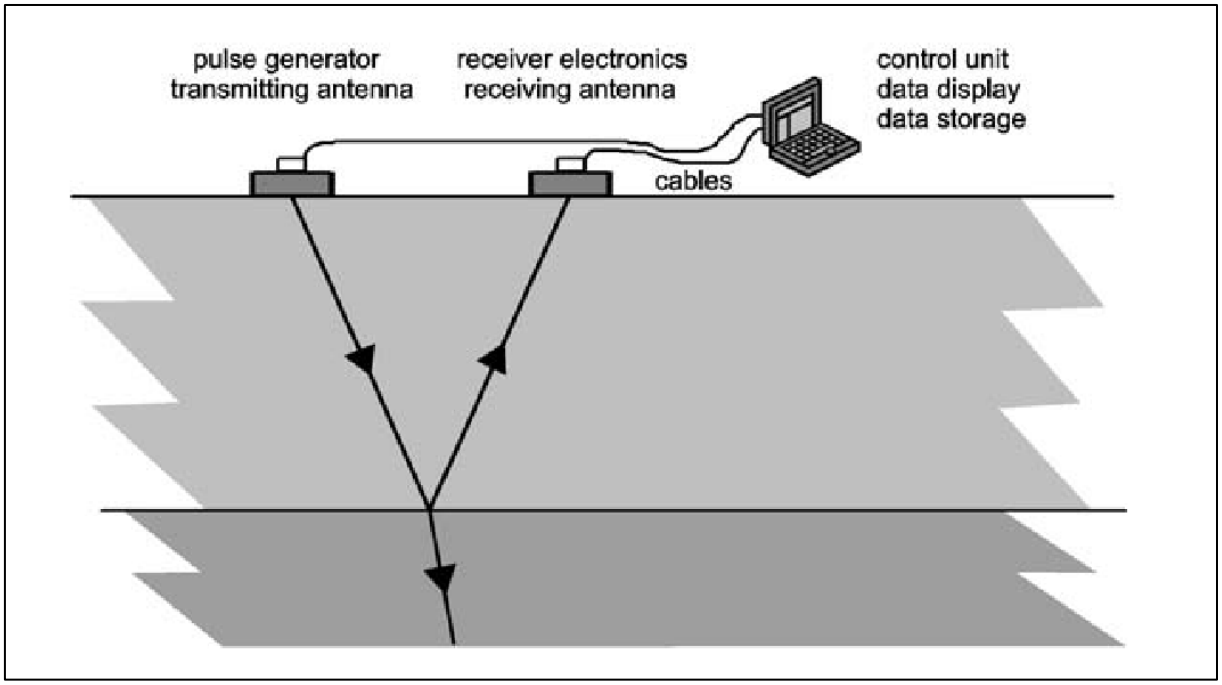


Figure 3.22: Ground penetrating radar acquisition (Krisch, 2006).

The cables connecting the different parts of a system are preferably nonmetallic fiber optic cables. If metallic cables are to be used some ringing or internal reflections may occur. Shielding and ferrite beads are used to suppress such artifacts. Although these components may look different for systems of different GPR manufacturers the principles of operation and even electronic circuitry is generally the same for time domain (i.e. short pulse) measurements. A novel class of frequency domain equipment (stepped frequency radar) not described here uses a different concept to get similar results (Krisch, 2006).

3.16 Input GPR Data

Seismic unix has the modifiable property with the tools of it. So it can use for GPR data preparing, viewing, processing and interpretation. The GPR data have

many formats differ with difference of manufacturer companies of GPR acquisition system. The GPR data can be transferred by SEG-Y format.

Some of GPR data come in two files one as in Tab (3.1) contain the data and the second contain survey conditions this the header are separated in other file with different file format as in Tab (3.1).

Table 3.1: GPR data formats.

Company name	Data file format	Header file format
Sensors & Software, Inc	DT1	HD
Malå GeoScience	RD3	RAD

Other GPR data format like SEG-Y and DZT of Geophysical Survey Systems, Inc. come in one file each of the data and the headers. In this thesis the GPR data was in rd3/rad format with file size 1.6 MB for rd3 file. It is 2D profile with long 284m and frequency 500Mhz.

3.17 GPR data conversion

The used seismic unix version support the dt1/hd format through the conversion tool (application) called dt1tosu while our data in rd3/rad format. In order to convert the GPR data to seismic unix format (su) we should use another tool.

For this purpose the recast tool was used.

```
$  recast < data.rd3 in=short out=float > a.f &
```

recast: convert from one data type to another.

in: the GPR data

out: initial data

```
$ suaddhead < a.f > data1.su ns=344 &
```

suaddhead: create headers.

ns: number of sample get it from rad file (original data header).

$ sushw < data1.su > data2.su dt=34400 &

sushw: set and change the header but don't create it.

dt: sample interval.

When data2.su formed the conversion of the data was end.

3.18 GPR data viewing

The seismic unix viewer tool which is suximage was used to view to convert data. In order to get reasonable image of the data the automatic setting of viewer should be change from seismic stander to GPR data standard. The GPR standard mean the time and distance interval of the data set that are available in HDR file or header file.

$ suximage < GPR data.su d1=1.75 d2=0.0999 &

d1: time interval in nano sec.

d2: distance interval in m.

Chapter Four

Data Processing

4.1 Preface

Data processing in general is changing data, usually to improve the signal to noise ratio to facilitate interpretation. Processing operations include applying corrections for known perturbing causes, rearranging the data, filtering it according to some criteria, combining data elements, transforming, migrating, measuring attributes, display. As a result each seismic data have adapted special processing procedure (flow) according to the processing parameter which result from testing the data.

Seismic data processing operations done with special processing softwares (programs) because of the huge data size and calculations. In this thesis a package program which is seismic Unix was used for processing. Seismic Unix is a standard set of computer processing routines which form tool (application). These tools forming seismic Unix which tailoring the processing to the specific needs of the data. Often implies back-to-back processing without intermediate decisions between stages in the processing.

A processing flow Fig (4.1) is a collection of processing routines applied to a data volume. The processor will typically construct several jobs which string certain processing routines together in a sequential manner. In this thesis the flow chart summarized all what have done on the data as in Fig (4.1).

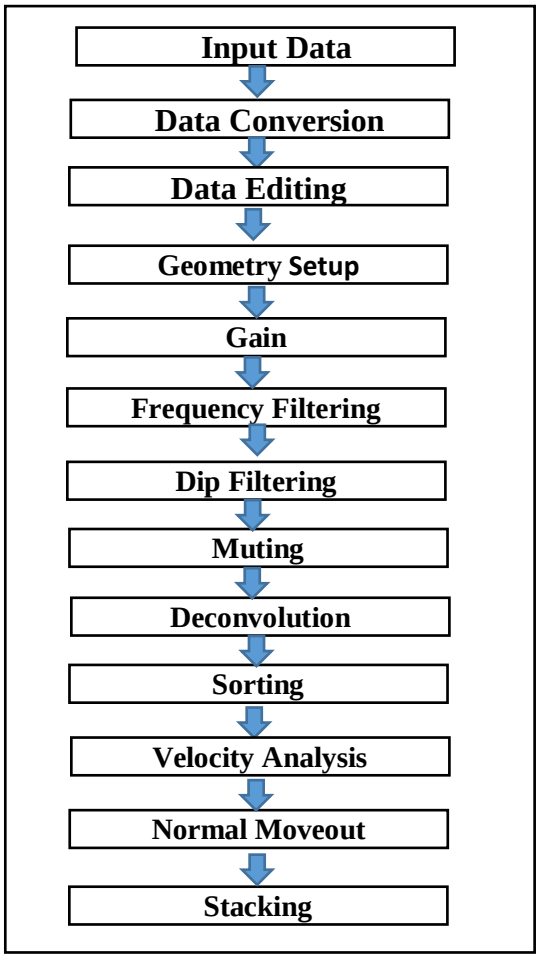


Figure 4.1: Processing flow chart of the processed data. This chart was developed through this study.

4.2 Input Seismic Data

The raw seismic data is available in the internet for example the official page of Society of Exploration Geophysics (SEG) "http://software.seg.org" but for this thesis a real seismic data from an area in Iraq was used. The location of the area of seismic data are restricted by the provider for security reason. The seismic data file's size before conversion (SEG-Y format) was 183.8 MB. The seismic data was formed from 164 shot between two shots 100m shot interval. the survey layout type is split spread each record have one shot (source point) and 96 receiver (geophone) distributed evenly 48 receiver on each side of the shot between two receivers 50m receiver interval.

The data contain 15744 trace each trace formed of 3000 sample with sampling rate 2 ms. The trace length result of multiplying samples number with the sampling rate (window) which is 6,000ms or 6 second as in Tab (4.1).

Table (4.1): Seismic data general information.

Information	Details
File name	bs
File format	Seg-y
File size	183.8 MB
Shot number	164
Shot spacing	100m
Receiver spacing	50m
Receiver number	96
Layout type	Split spread
Fold coverage	48 fold
Trace number	15744
Sampling window	2 msec
Sample number	3000
Record length	6 sec

Some of this information already exist in the trace header and others not. The data information can be classified according to their usage in processing sequence so that they will be differ some of them will calculated and other will synthesis to helped in calculation.

4.3 Data Conversion

The file size still same after conversion because the absence of the textual (EBCDIC) header which is related to data exportation method. The data format changed from seg-y to su (seismic Unix format) in order to be read by seismic Unix.

The conversion done when the data trace header can be read by seismic Unix. The trace header information represent the first and primitive defined (in seismic Unix) information of the data as in table (4-2).

Table 4.2: Defined trace header in seismic Unix.

Information	Details
Traces number.	15744
Trace sequence within survey in su format (tracr).	(1 - 15744)
Trace sequence within survey in seg-y format (tracf).	(1- 15744)
Shot number sequence (fldr).	(1 – 164)
Trace sequence within shot (tracf).	(1 – 96)
Trace identification code (tride).	1
Sample number (ns).	3000
Sampling window (dt).	2 msec

4.4 Viewing Data

The seismic data should be checked to identify the missing shot(s) as in Fig (4.2), bad shots, noisy traces as in Fig (4.3) and missing samples as in Fig (4.2).

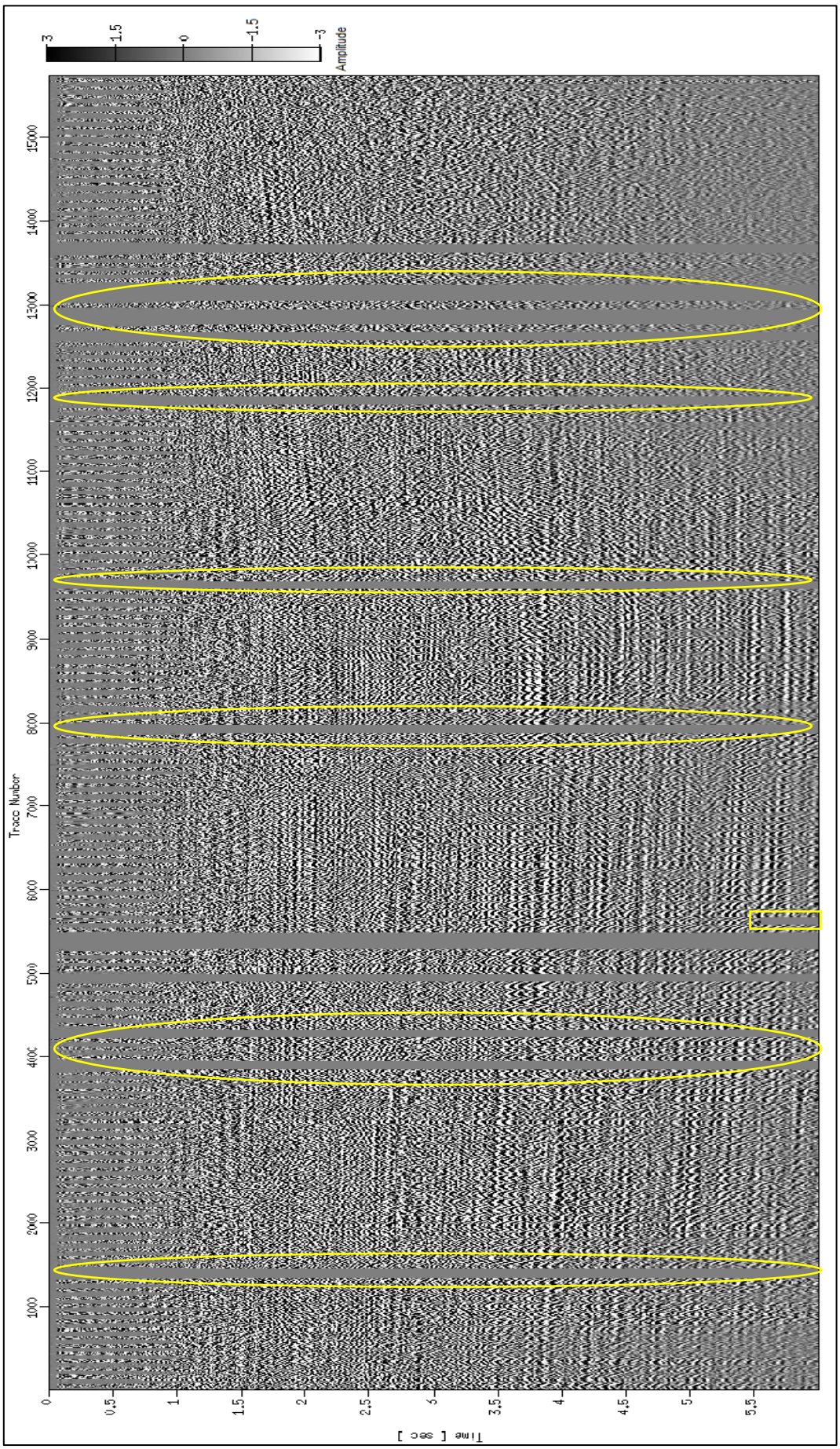


Figure 4.2: Seismic data image with a small scale. The yellow elliptical represent missing shots. The yellow rectangle missing samples from record. All these stripes which some of them shaded by yellow elliptical are missing shots.

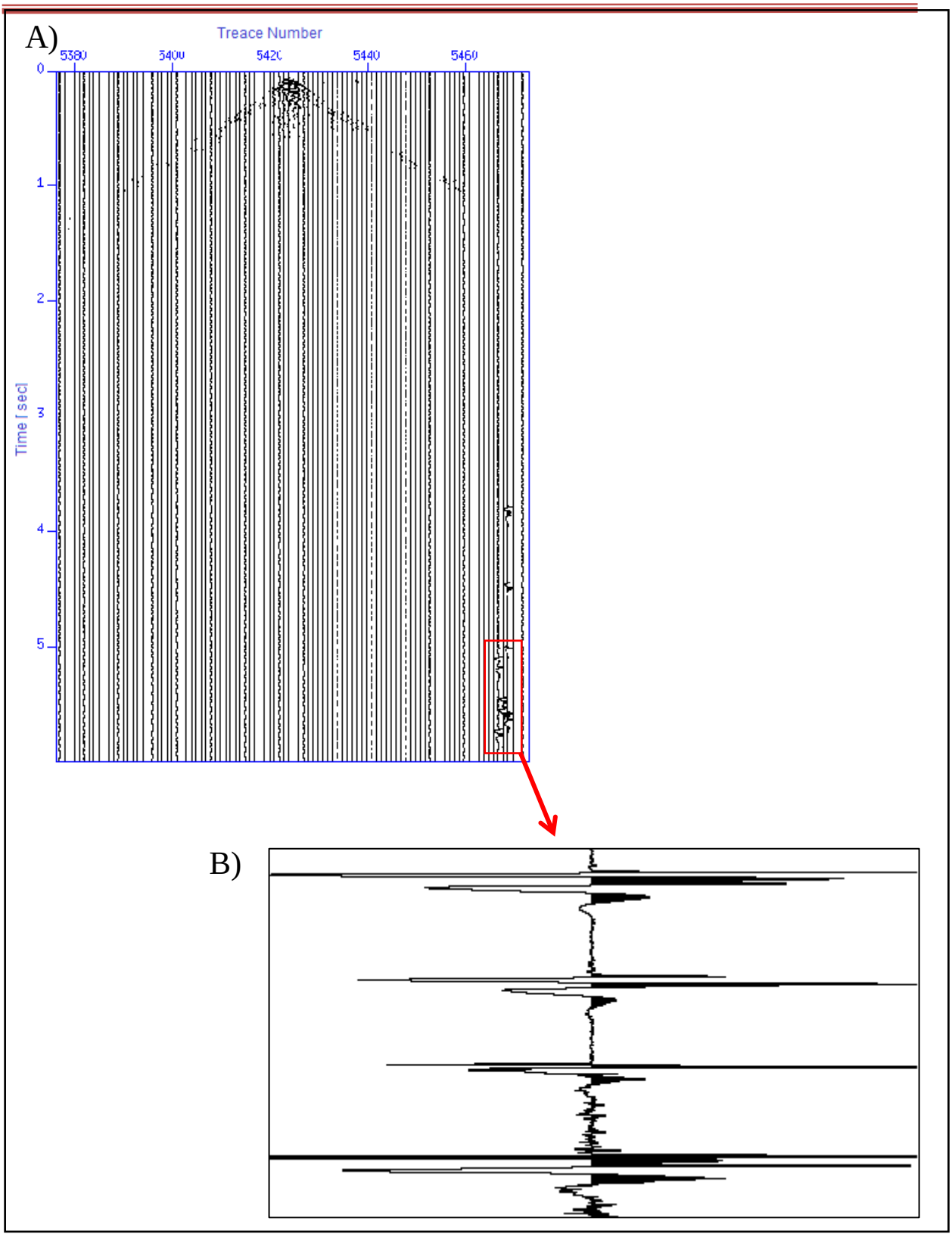


Figure 4.3: Noisy trace. A. shot gather with noisy trace. B. magnified part of the noisy trace.

4.5 Data Editing

The data set contain many bad shots as in table (4.3) which are rejected from the data. After rejection the bad shots the trace and shot number will be reduce. The numbering sequence also differ so the data should be reset.

Table 4.3: Bad shots and noisy traces.

Rejected shots		Killed traces	
Number	Shot Number	Number	Noisy trace Number
1	15	1	2204
2	31	2	3264
3	35	3	5465
4	52	4	5466
5	56	5	5467
6	57	6	5468
7	83	7	5469
8	101	8	5470
9	124	9	5471
10	132	10	5472
11	134	11	5473
12	135	12	13464
13	137	13	13465
14	138	14	13466
15	143	15	13467
		16	13468
		17	13469
		18	13470
		19	13471
		20	13754

All the data set will be shifted after the rejection the shot number 16 will be 15 when the shot 15 reject and so on. The data will be continuous without missing as in Fig (4.4). The traces length are equalized as in Fig (4.4).

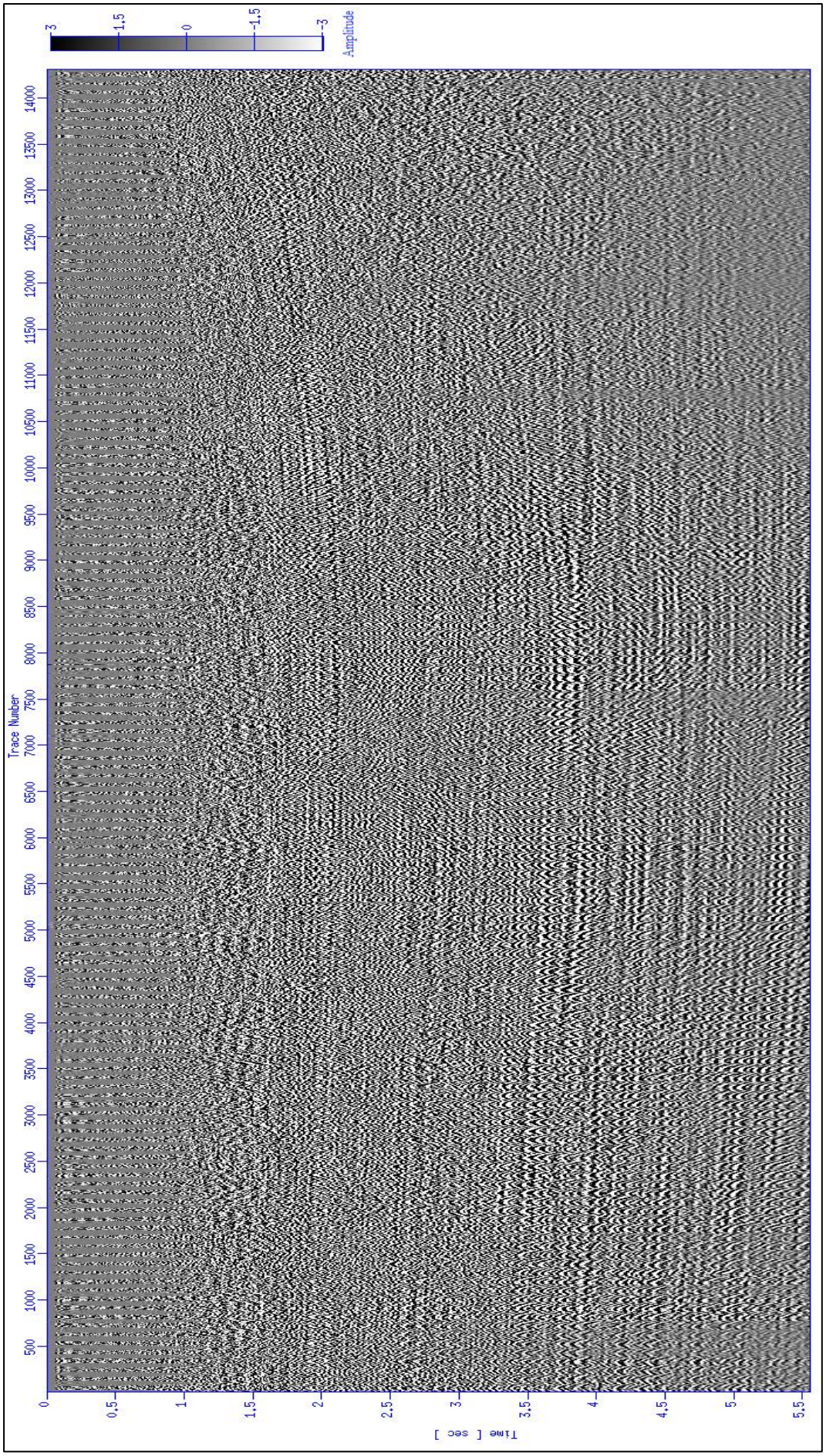


Figure 4.4: Seismic data after reject bad shots and trace equalize.

4.6 Geometry Set Up

At this stage the geometry of the data suffer from many losses because of early processing like rejection as in Fig (4.5) and the limited trace header information. The normal move out correction and velocity analysis need the data to be sorted in the common depth point domain (CDP) and offset domain. In order to create these domains need to shots (sx,sy) and geophones (gx,gy) position. According to the early knowledge about the survey area the dip of it gentle dip which have minimum effect on data so the (sy,gy) will be neglected. As result (sx,gx) will be defined in relative way by projection them on an imagery x-axes of Cartesian coordinate system.

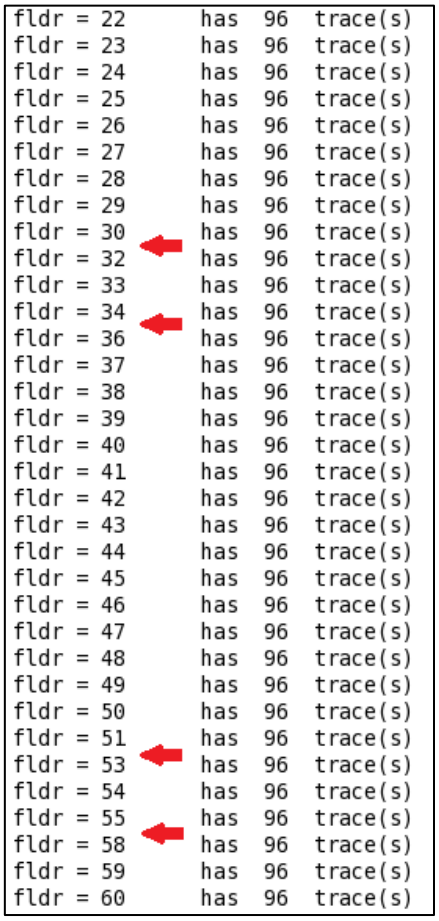


Figure 4.5 : A snapshot of header exported as a file showing a sample of shots arrangement and reject shot shaded by red arrow.

The geometry of the data wrote in the traces header as a result the new trace headers formed as in Tabel (4.4).

Table 4.4: Trace header after geometry setup.

Header information	Details
Traces number	14304
Trace sequence in survey (tracl)	(1 - 14304)
Trace sequence in original seg-y (tract)	(1 - 14304)
Shot number (fldr)	(0 - 148)
Trace sequence with shot (tracf)	(1 - 96)
Cdp number (cdp)	(1 - 540)
trace number within cdp (cdpt)	(1 - 32)
Trace identification code (trid)	1
offset	(-2375 - 2375)
sx	(0 - 14800)
gx	(-2375 - 9775)
Number of sample (ns)	2777
Sampling window (dt)	2 msec

4.7 Amplitude Recovery

Two gain function are applied exponential and time power gain as in tabel (4.5).

Table 4.5: Tested gain combinations

Time power gain (tpow)	Exponential gain (epow)
2	1
1	2
1	0.5
1	1
0.5	0.25

Many combination of them tested until get the appropriate one see Fig(4.7-12). In order to calibrate the amplitude recovery of the data and because the huge size of the detail in the data set it is better to view the processing results on one seismic shot or in the shot domain. The selected shot should be have clear reflectors so that the processing result be obvious as in Fig(4.7). In amplitude recovery the amplitude spectrum give clear imagination of energy distribution through all shot which represent the seismic data set. We can compare between the amplitude spectrum of the shot with same gain function but with different values as in Fig (4.6). Through the tests of the amplitude recovery the time power gain equal to 1 (tpow=1) and exponential gain equal 0.5 (epow=0.5) give uniform energy distribution as in Fig (4.12), while others suffer of uneven energy distribution . In Fig (4.7 to 12) is the comparison in the shot domain where the Fig (4.7) represents the original shot without gain and Fig (4.8 to 12) represent the different gain combination values. The Fig (4.12) is the best gain result that coincides with result of Fig (4.6-F).

4.8 Frequency Filter

The frequencies values table (4.6) which are used to filter tested each one alone. The best values that maximize the resolution and decrease the noise as possible with no effect on reflectors. The frequency filter test done through the comparison in shot domain where the original shot without filter, reject noise and passed data for each frequencies values in Tab (4.6).

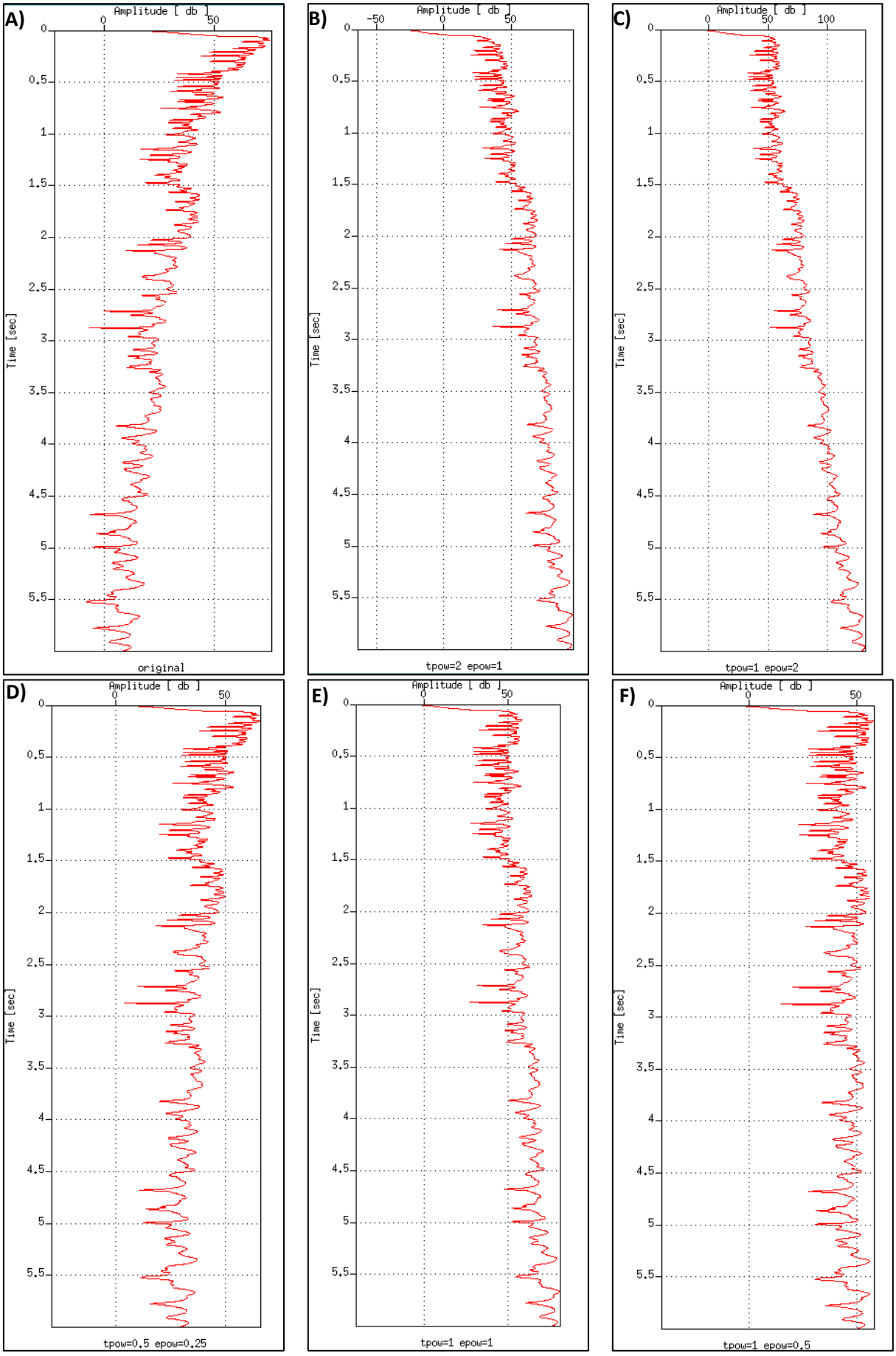


Figure 4.6: Amplitude spectrum comparison of different gain combination.

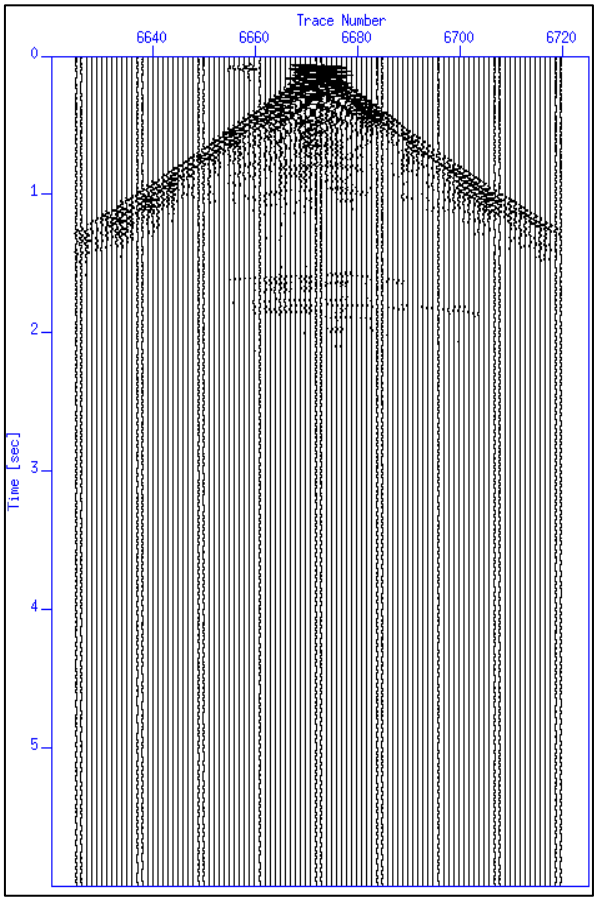


Figure 4.7: shot without gain.

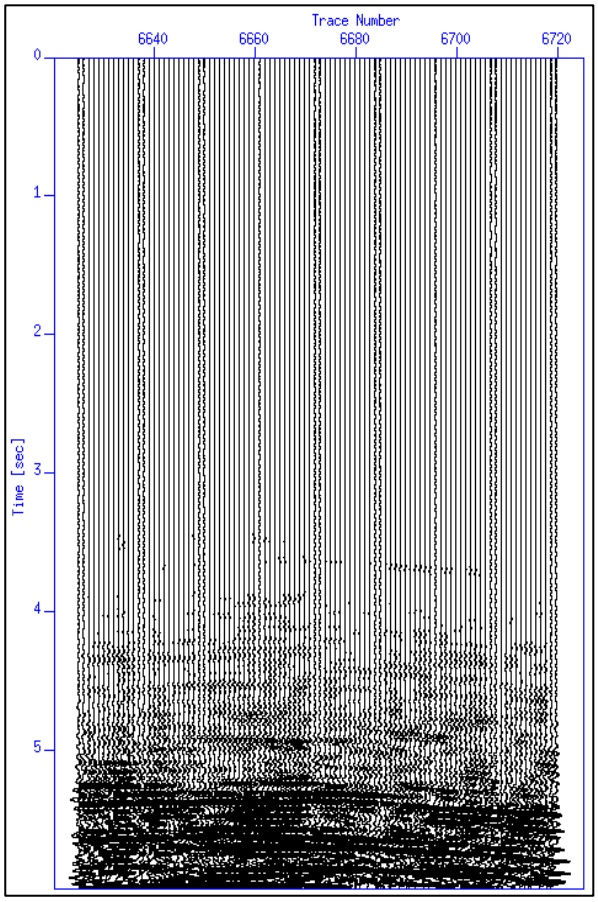


Figure 4.8: shot with tpow =2 & epow =1.

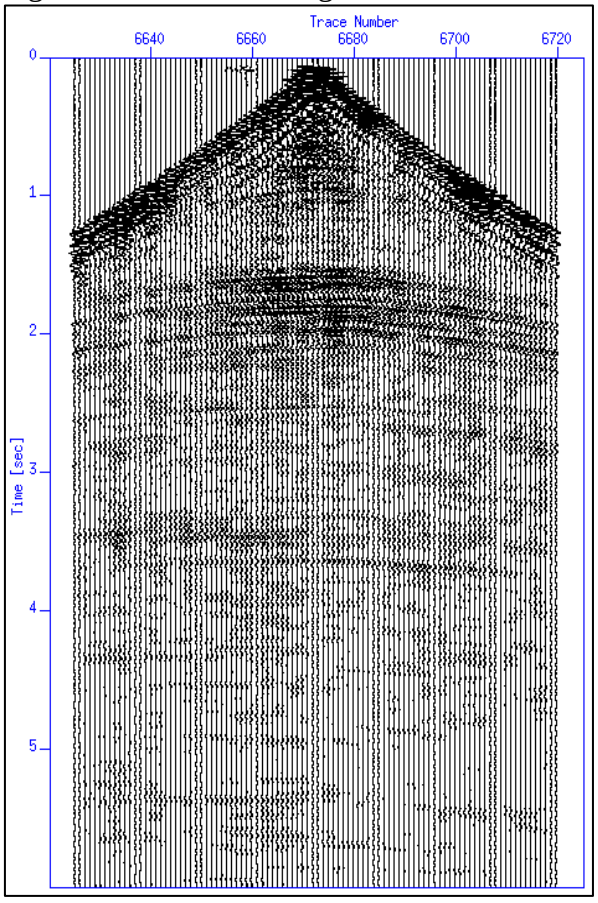


Figure 4.9: shot with tpow =0.5 & epow=0.25

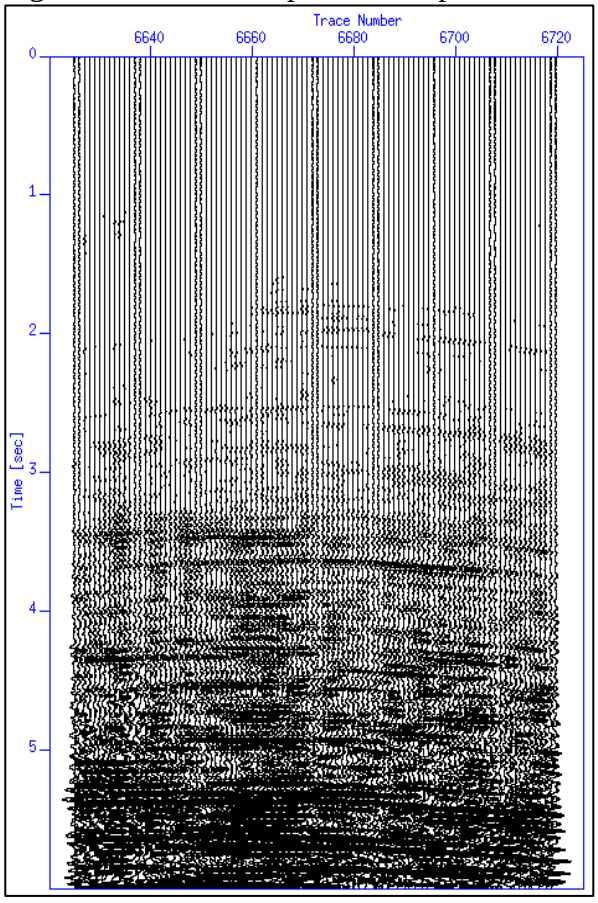


Figure 4.10: shot with tpow =1 & epow=1.

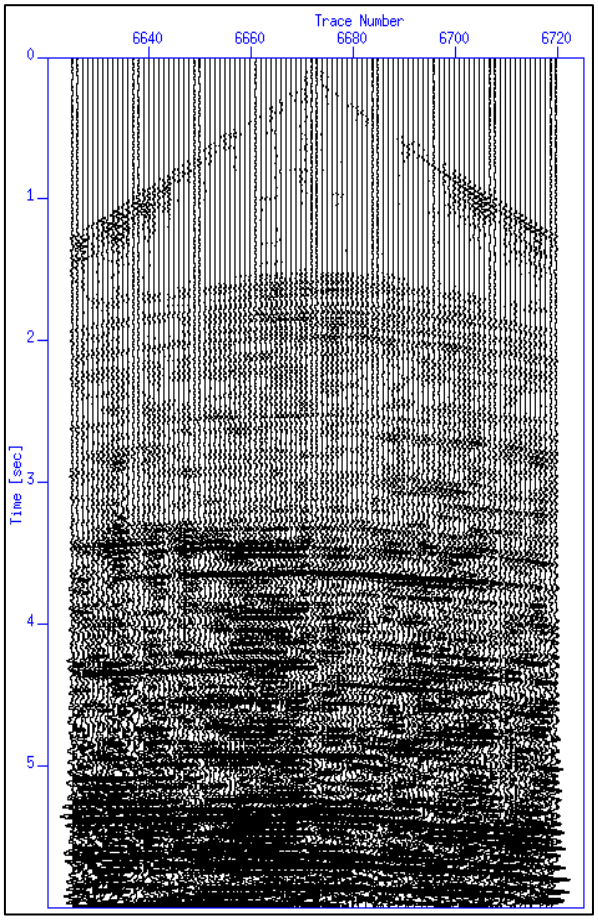


Figure 4.11: shot with tpow =1 & epow =2.

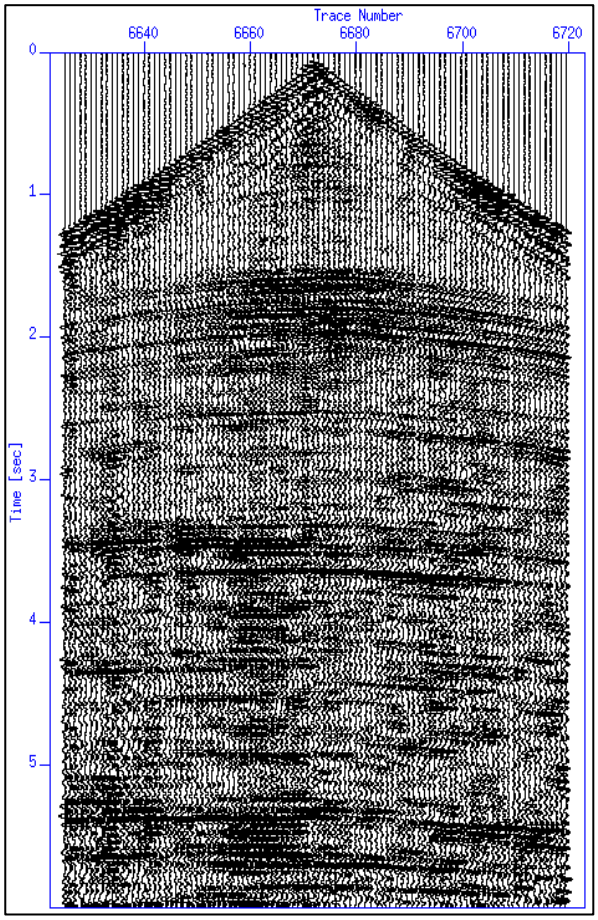


Figure 4.12: shot with tpow =1 & epow =0.5.

Table 4.6: possible frequency filter designs.

Design number.	Frequncy values.
1	0,5,45,50
2	5,10,40,45
3	5,10,45,50
4	10,15,45,50
5	5,15,45,55

After testing the frequencies the best obtained result was at f=5,10,45,50 as in Fig (4.15). In the bandreject Fig (4.15 B) the ground roll noise is so obvious that specified by two red arrows. While in bandreject Fig (4.16 B) the filter is harsh and the reflectors affected by it where it is obnouse that there are some parts of the reflectors ware rejected which specified by red arrow.

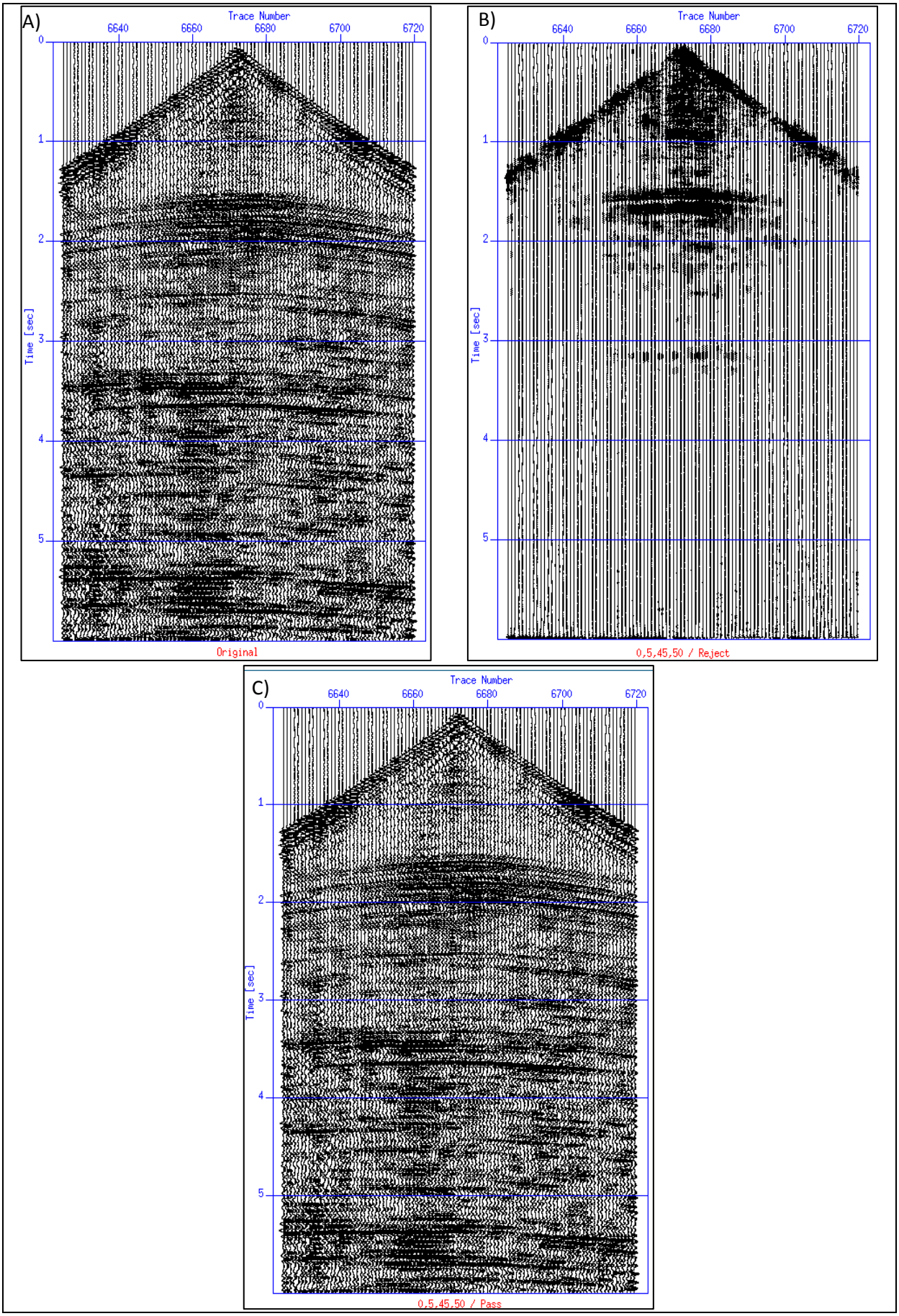


Figure 4.13: Frequencies=0,5,45,50 . A. original data. B. bandreject noise. C. filtered data.

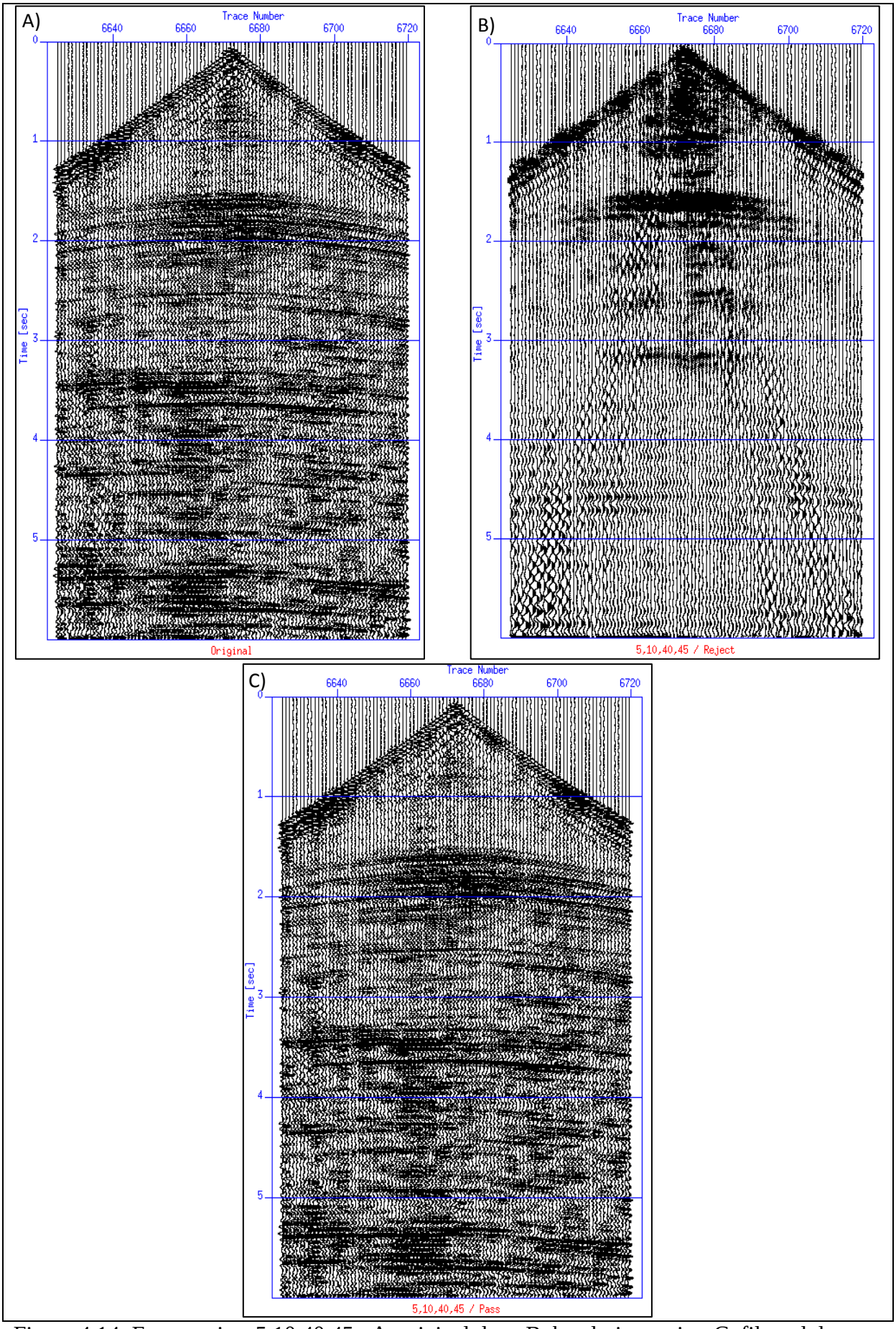


Figure 4.14: Frequencies=5,10,40,45 . A. original data. B. bandreject noise. C. filtered data.

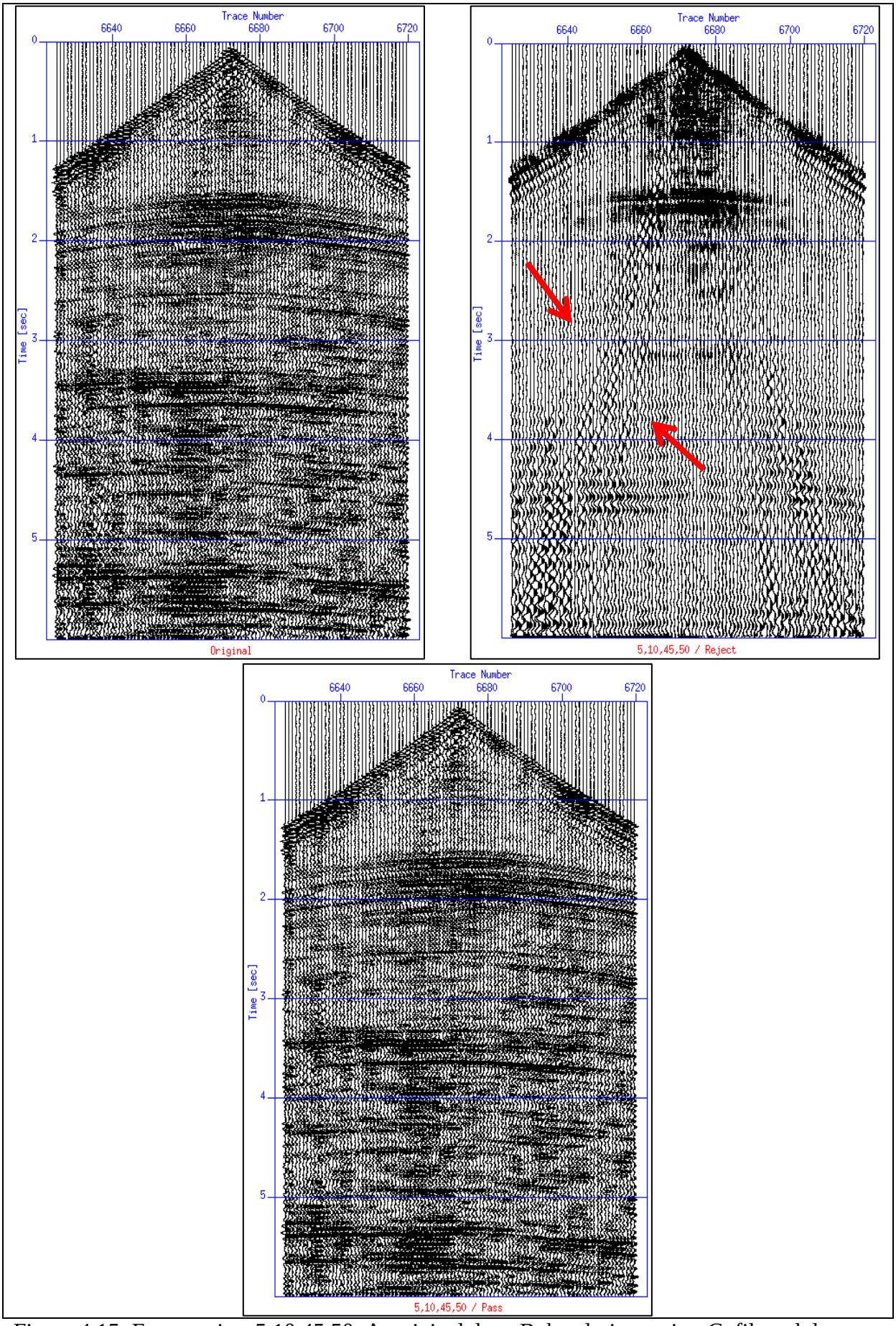


Figure 4.15: Frequencies=5,10,45,50. A. original data. B. bandreject noise. C. filtered data.

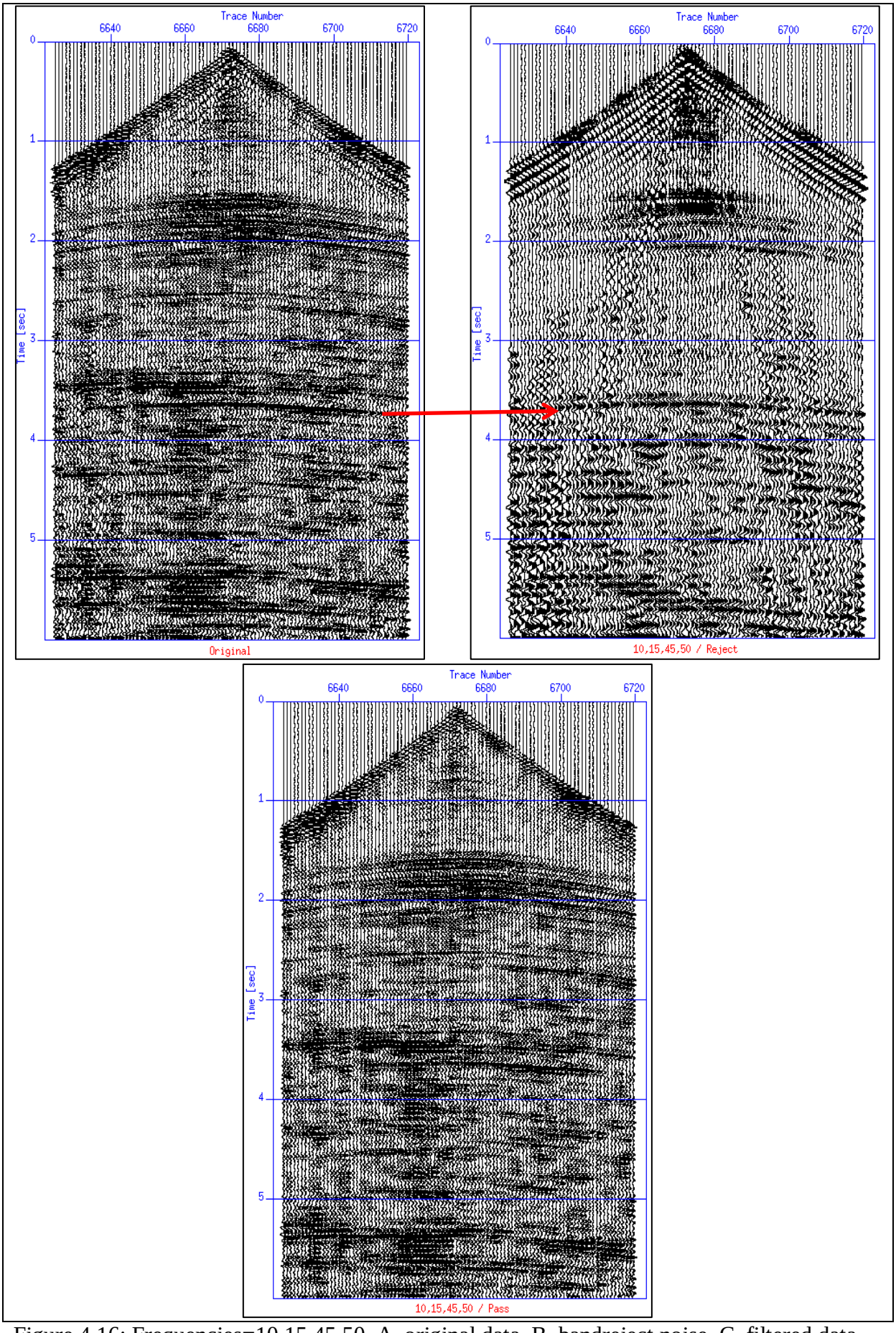


Figure 4.16: Frequencies=10,15,45,50. A. original data. B. bandreject noise. C. filtered data.

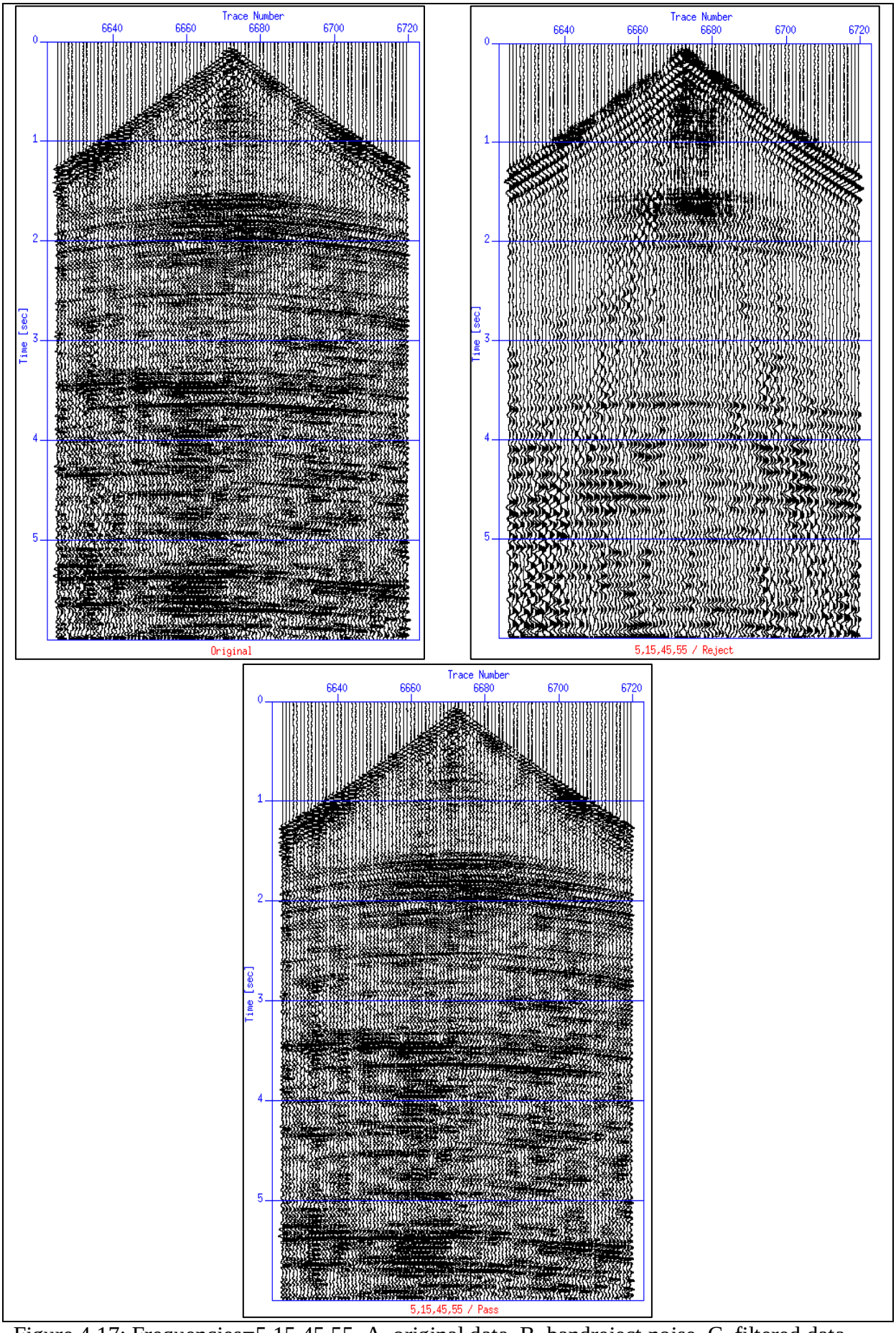


Figure 4.17: Frequencies=5,15,45,55. A. original data. B. bandreject noise. C. filtered data.

4.9 F-K (Dip) Filter

The best method of designing dip filter is to create the frequency – wave number spectrum of the data the noise will appear as slopes in F-K domain as in Fig (4.18). The black arrows in Fig (4.18) represent the noise in F-K domain.

The chosen dip window in Fig (4.19) which its bounders specified by to two radial black lines gives its result in Fig (4.20).

In Fig (4.19) the black arrows that are between the redial lines represent the range of bandreject window that are oriented on the noise. While everything outside the radial lines represent the pass data.

After applying F-K filter in Fig (4.20 A) the reflectors ware enhanced as the red arrow indicate.

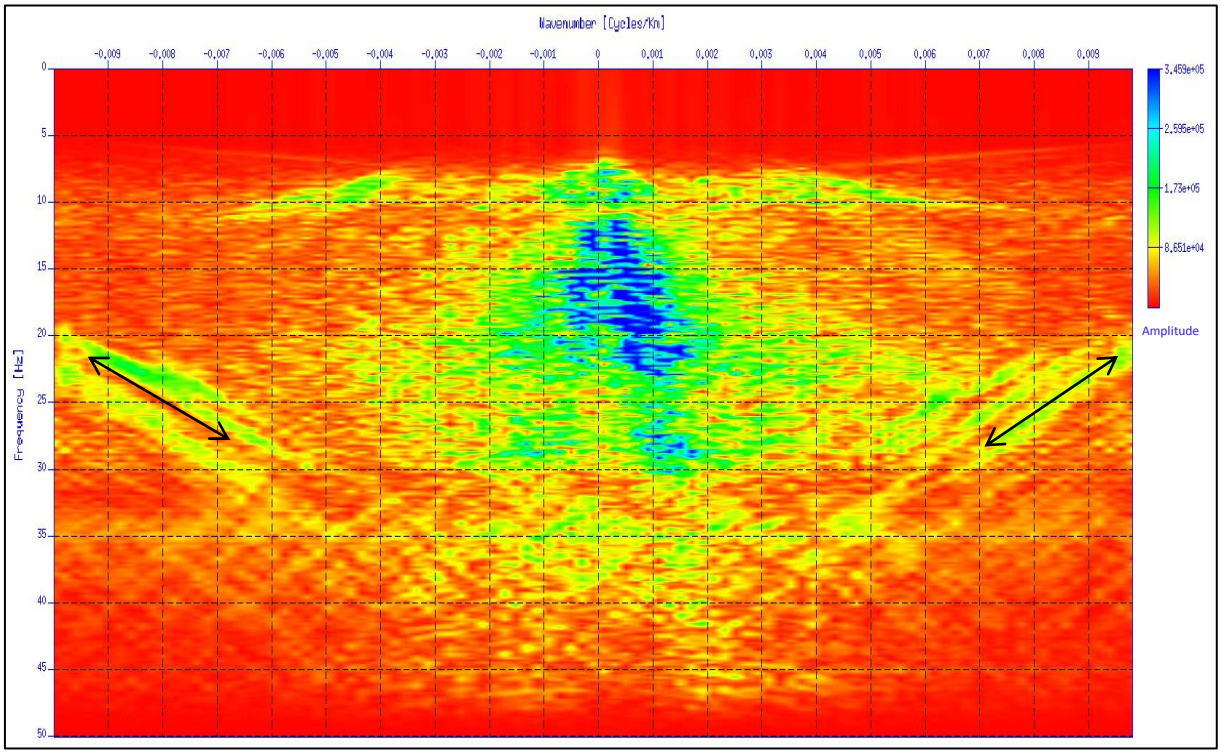


Figure 4.18: F-K spectrum. Black rows represent noise which it represented as slopes.

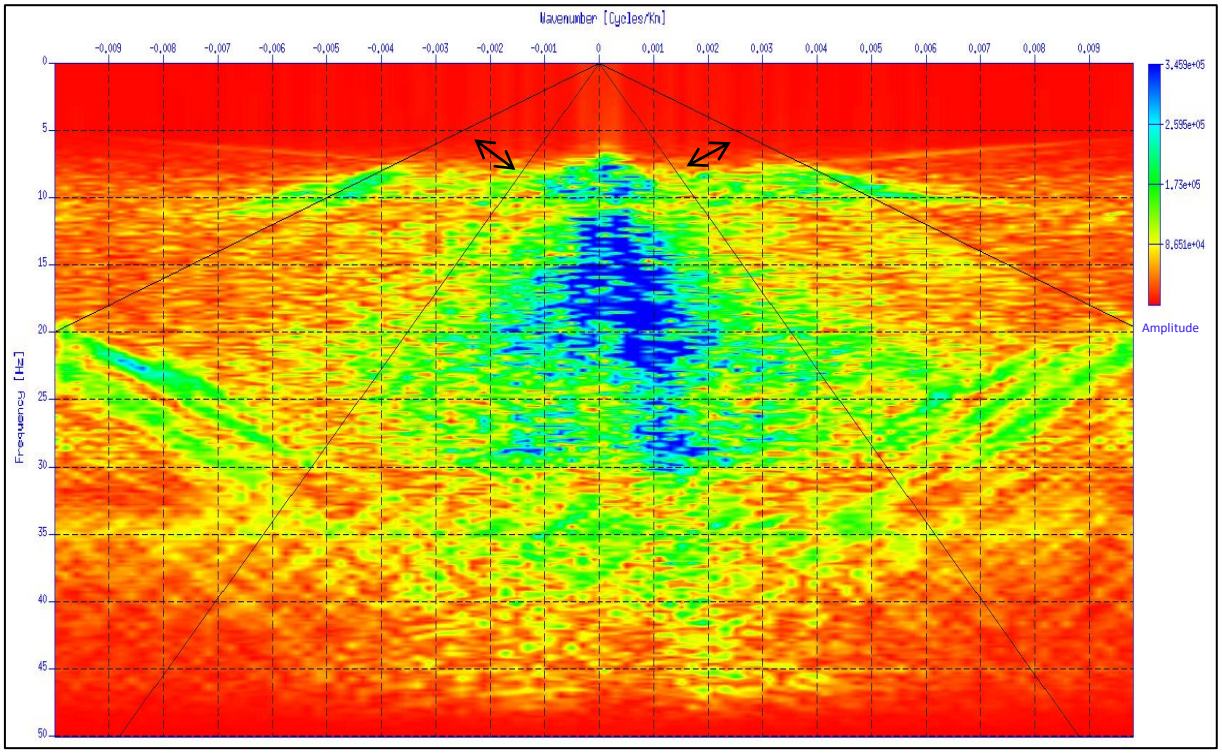


Figure 4.19: F-K spectrum. Black rows represent cutting window of the filter.

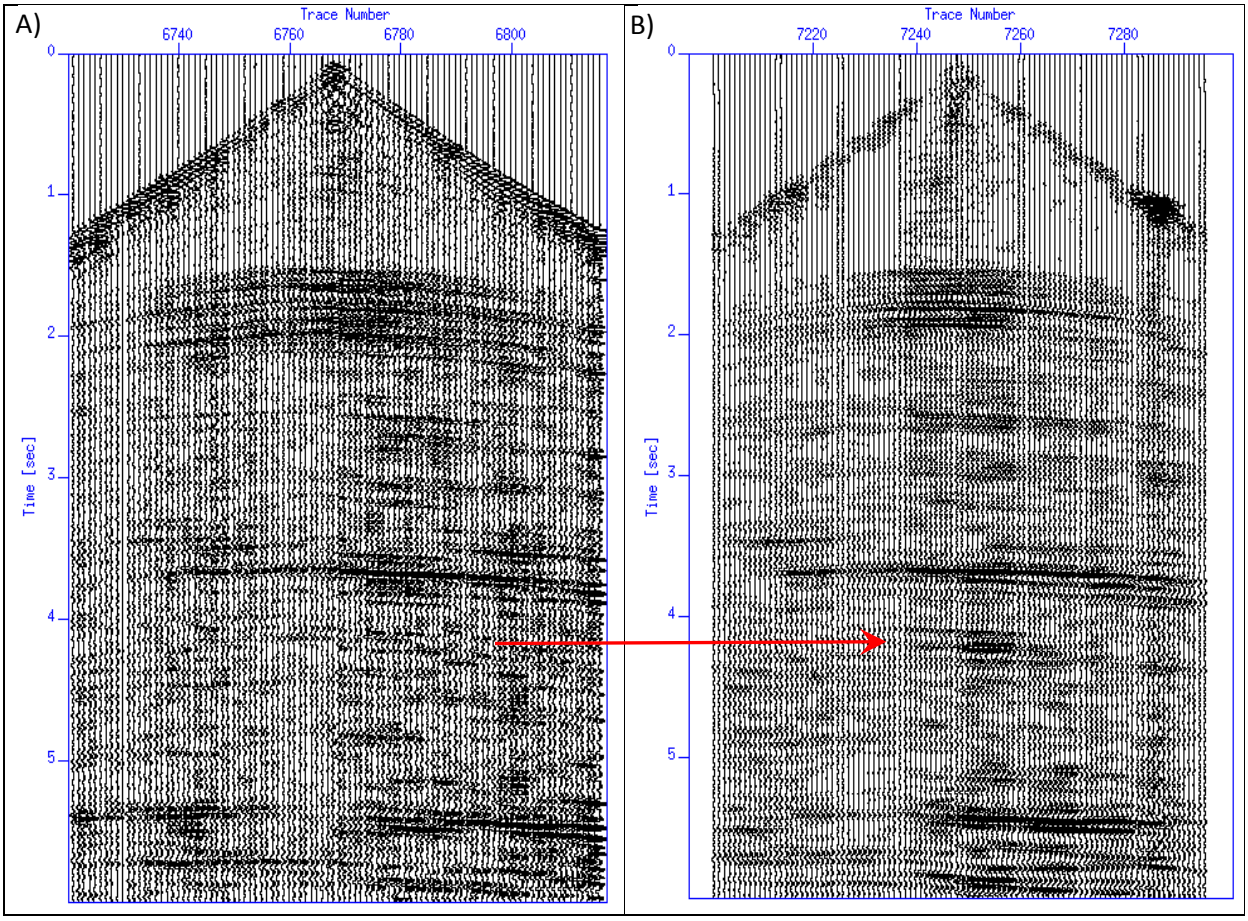


Figure 4.20: seismic shot. Left before F-K filter. Right after F-K filter.

4.10 Muting

The data should be muted before deconvolved. The noise affect deconvolution process. In Fig (4.21) the upper section of the data is not filtered the noise and first arrivals are obvious.

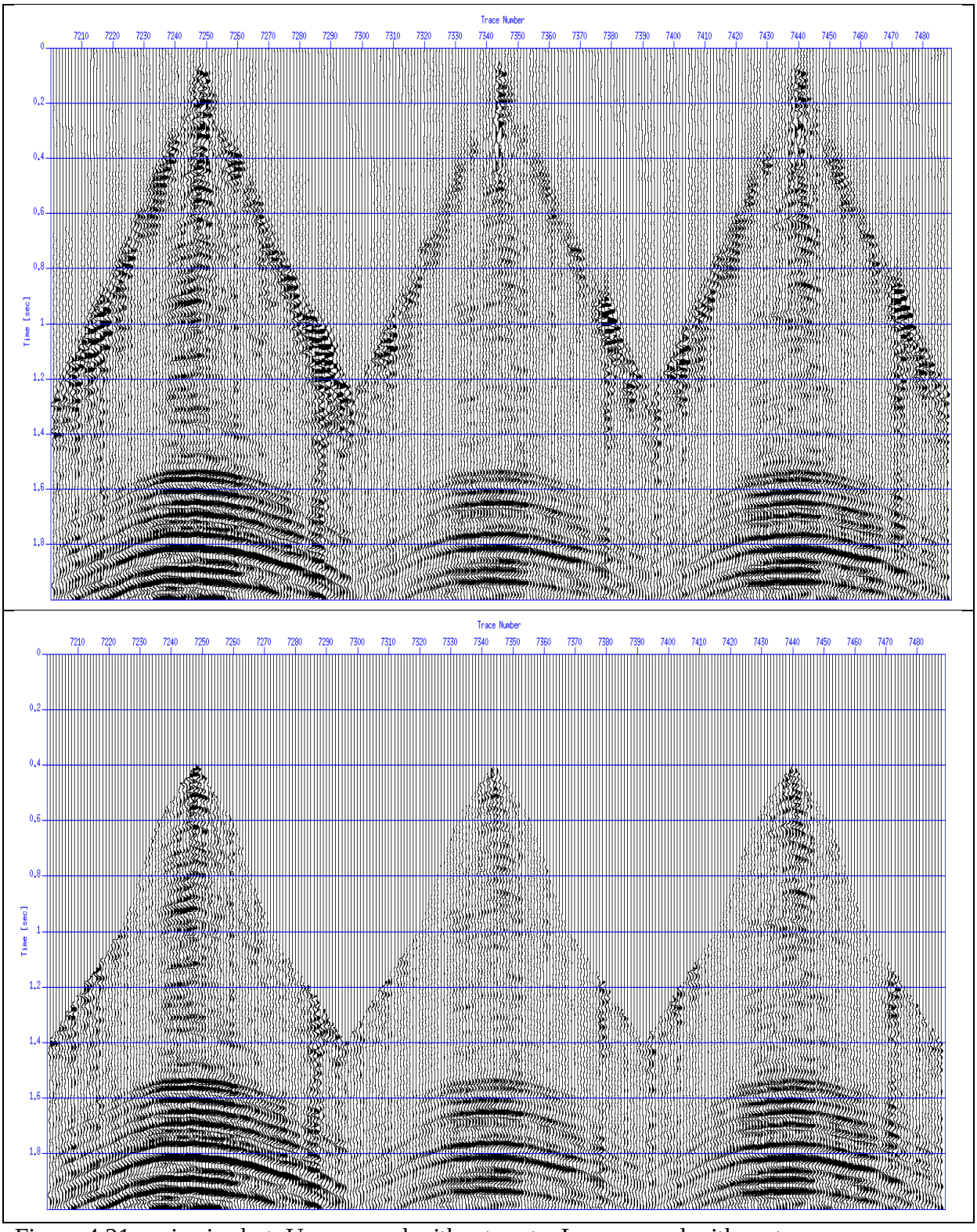


Figure 4.21 : seismic shot. Upper panel without mute. Lower panel with mute.

The first arrivals have harmful effect on the later reflectors in seismic section as in lower part of Fig (4.21).

4.11 Deconvolution and Autocorrelation

In order to decide the deconvolution performance the autocorrelation should be done before and after the deconvolution processes. The multiples will be appear as a strips in the autocorrelation window distributed on each side of the reflector as in Fig (4.22). The proper choosing of deconvolution parameters will eliminate these stripes.

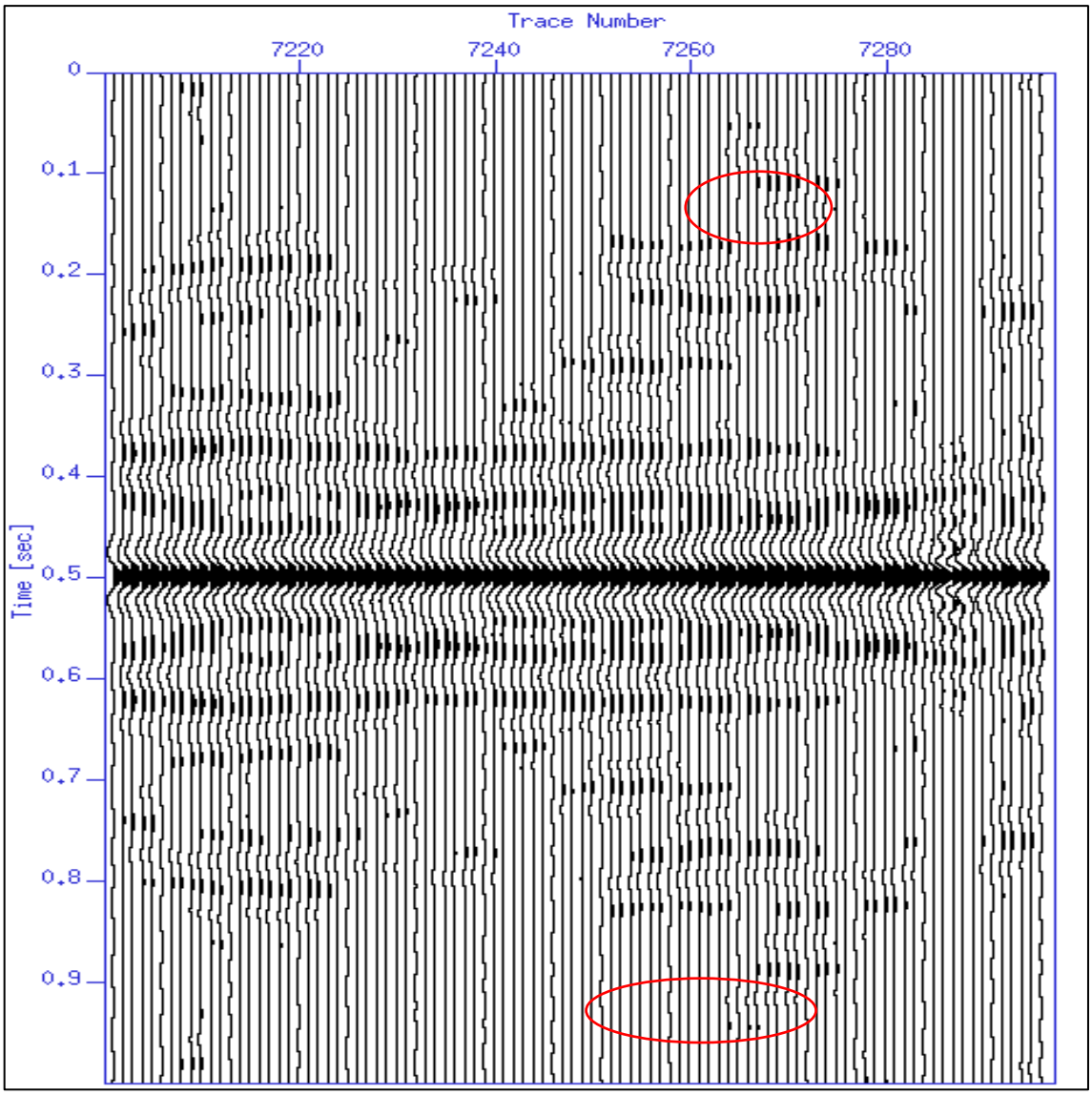


Figure 4.22: top view of autocorrelation window. There are many stripes in the window with different shapes and positions. The red elliptical shaded example of stripes. The central black line represent the reflector.

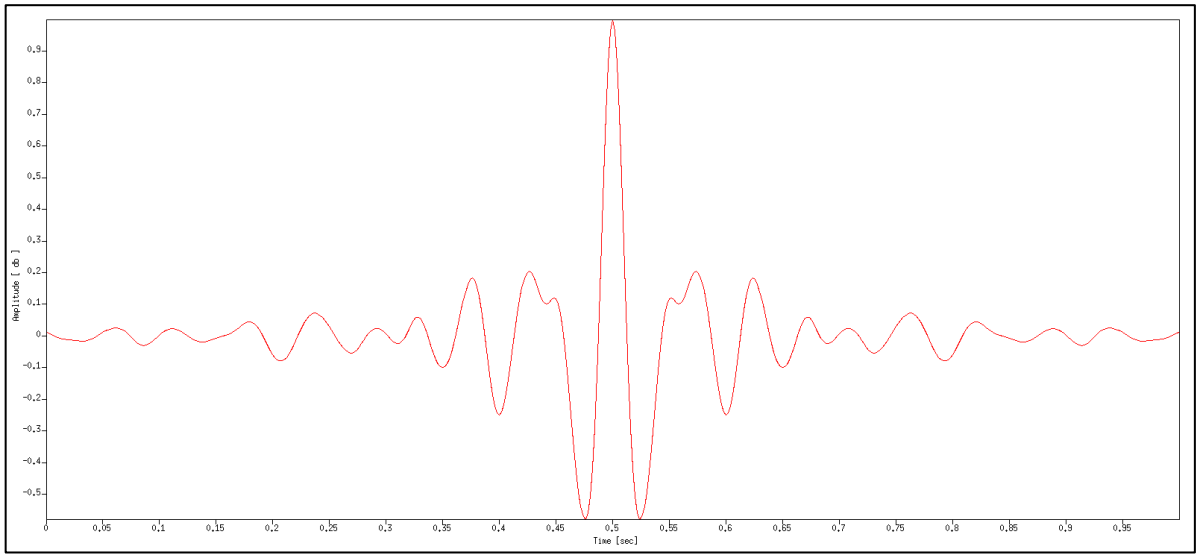


Figure 4.23: side view of autocorrelation window of (figure 4.22). The central peak represent the reflector and the other small peaks represent the multiples.

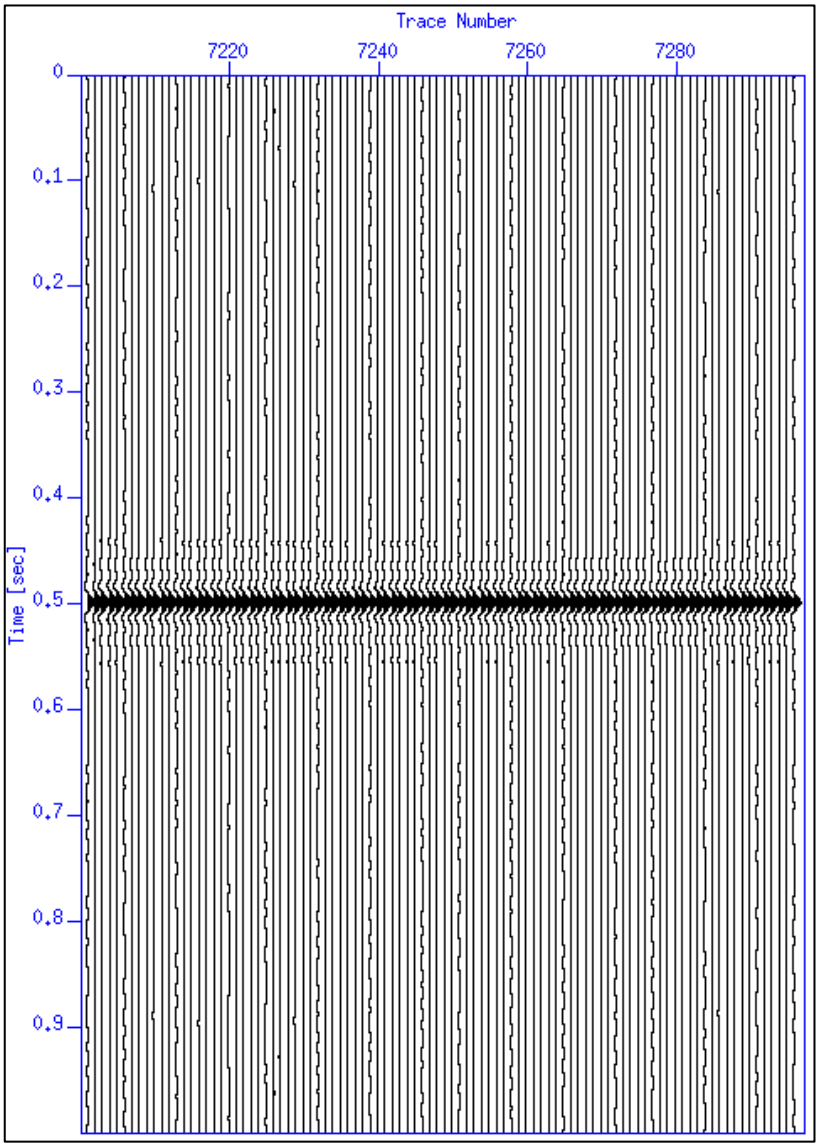


Figure 4.24: autocorrelation window after deconvolution. The strips ware eliminated.

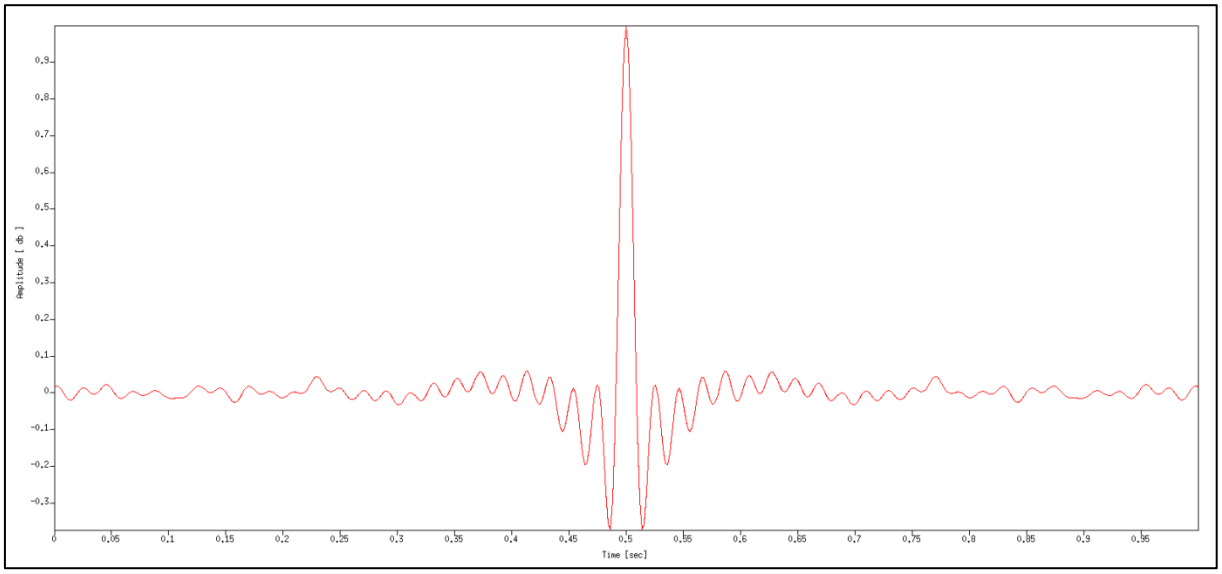


Figure 4.25: side view of autocorrelation after deconvolution.

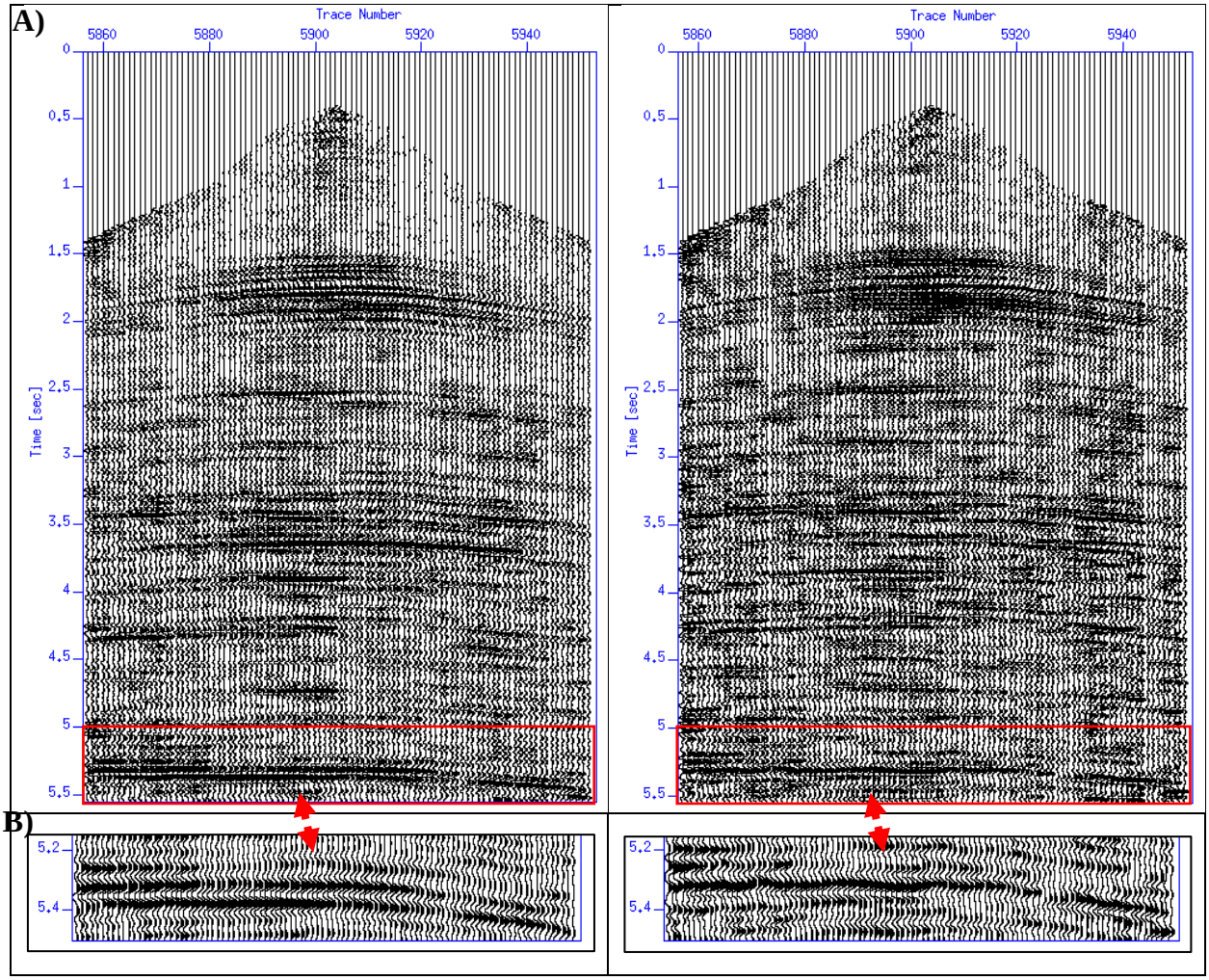


Figure 4.26: seismic shot comparison. A. Left panel before deconvolution right panel after deconvolution. B. Magnified part of the seismic shot as shaded by red arrows.

4.12 Sorting

The shot domain was used more than other domains in processing but the velocity analysis need the data in common depth point domain (CDP). There is a difference between the two domains as in Fig (4.27).

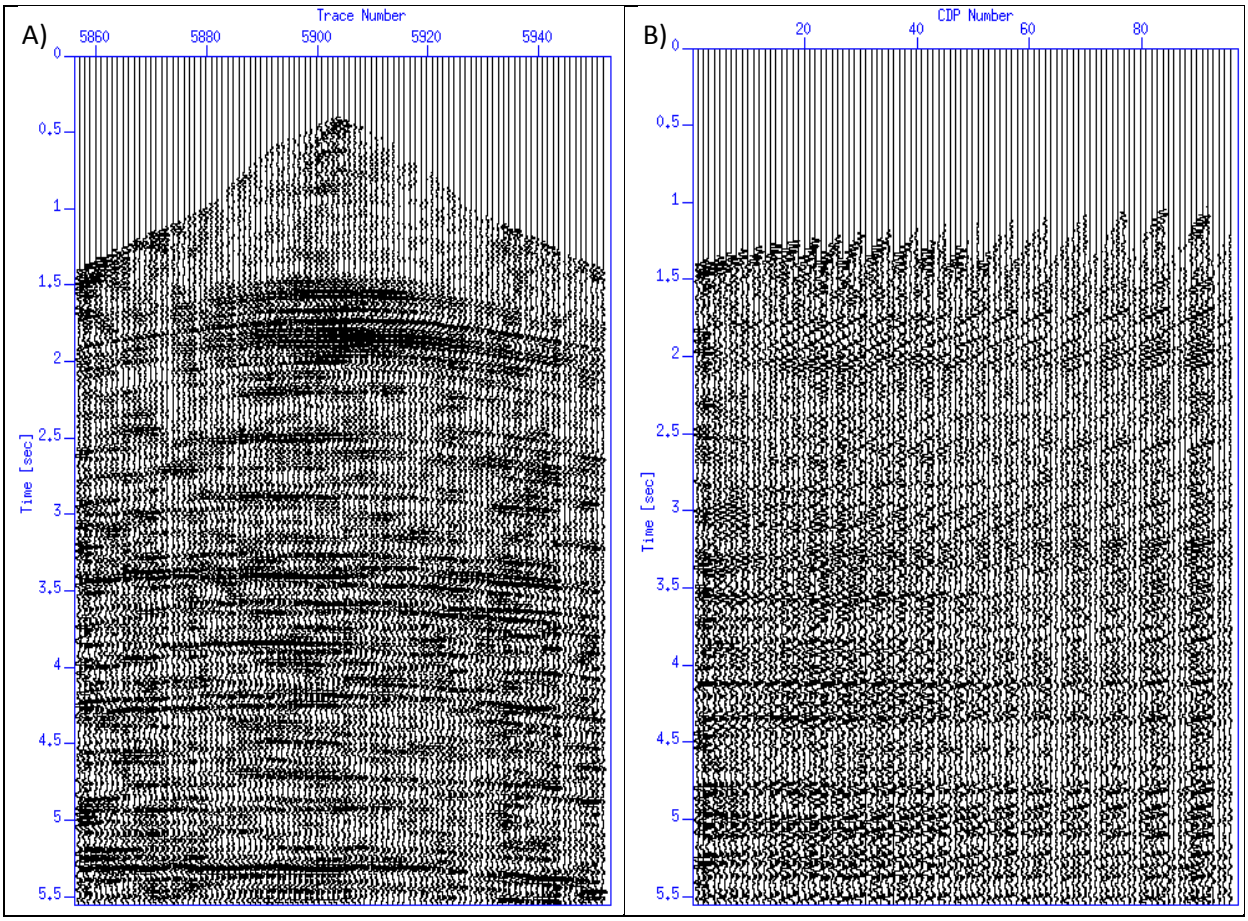


Figure 4.27: seismic domains. A. shot domain. B. CDP domain. The two picture with same traces quantity but with different array.

4.13 Velocities Picking and Normal Moveout Correction

The velocities picking is so careful and sensitive process. It is sometimes tricky. The chosen cdp's to the velocity analysis play a rule in the accuracy of picking by how much the fold of it. Some cdp's have distinct train of velocities as in Fig (4.28 B) and some of them not.

The picking should be distributed over all velocities as in Fig (4.28 B) that are represented through the analysis panel in order to get equalized normal moveout correction (nmo) as in Fig (4.28 C). The correct nmo make reflectors flat while the bad one like smile or frown.

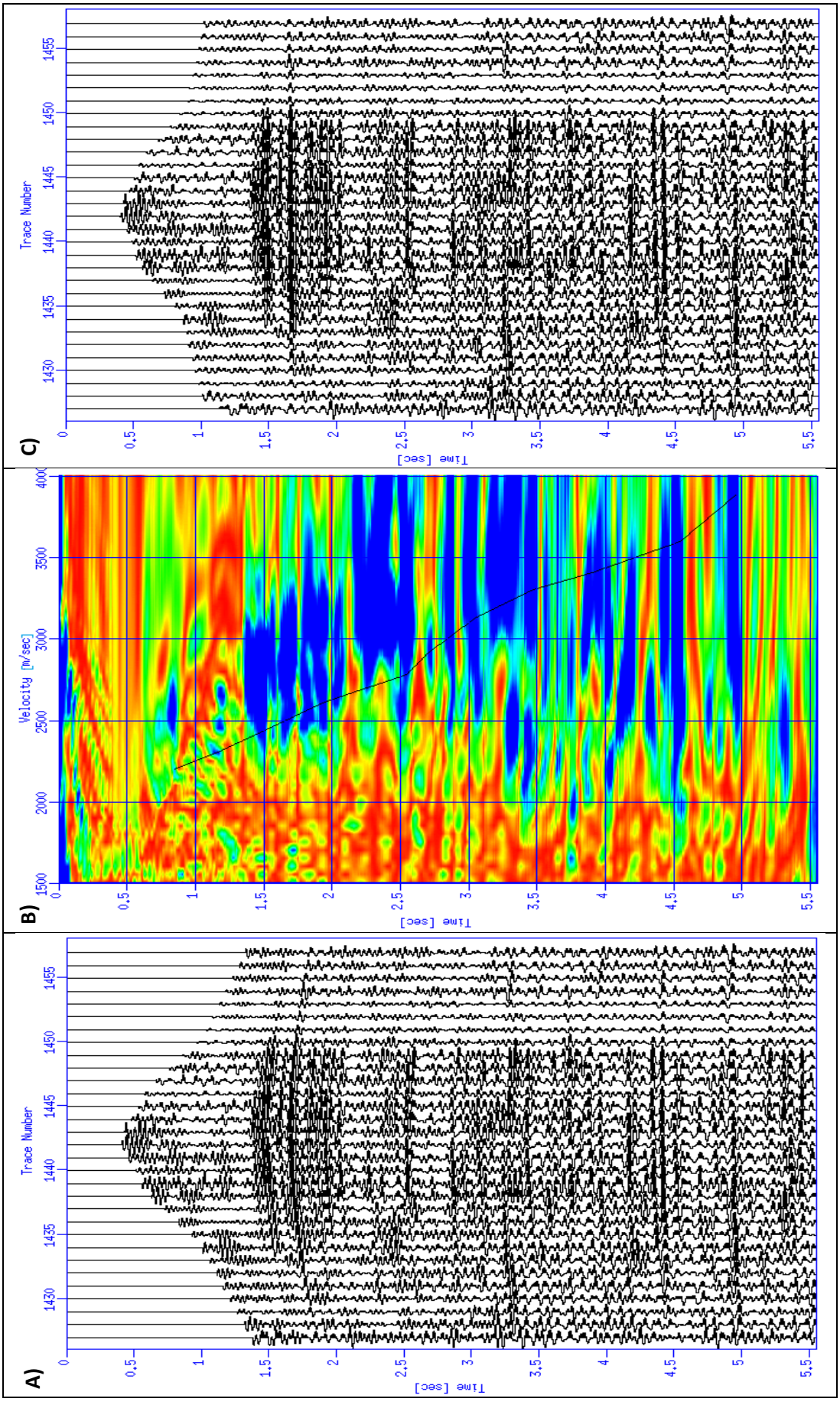


Figure 4.28: velocity pick and nmo correction. A. Data before nmo correction. B. velocity analysis and picking of the data in section A. C. data after nmo correction.

4.14 Stack

At the stack process the processing procedure was finished for this thesis. The comparison between the Fig (4.29) and Fig (4.2) will show as the wide in resolution and signal to noise ratio.

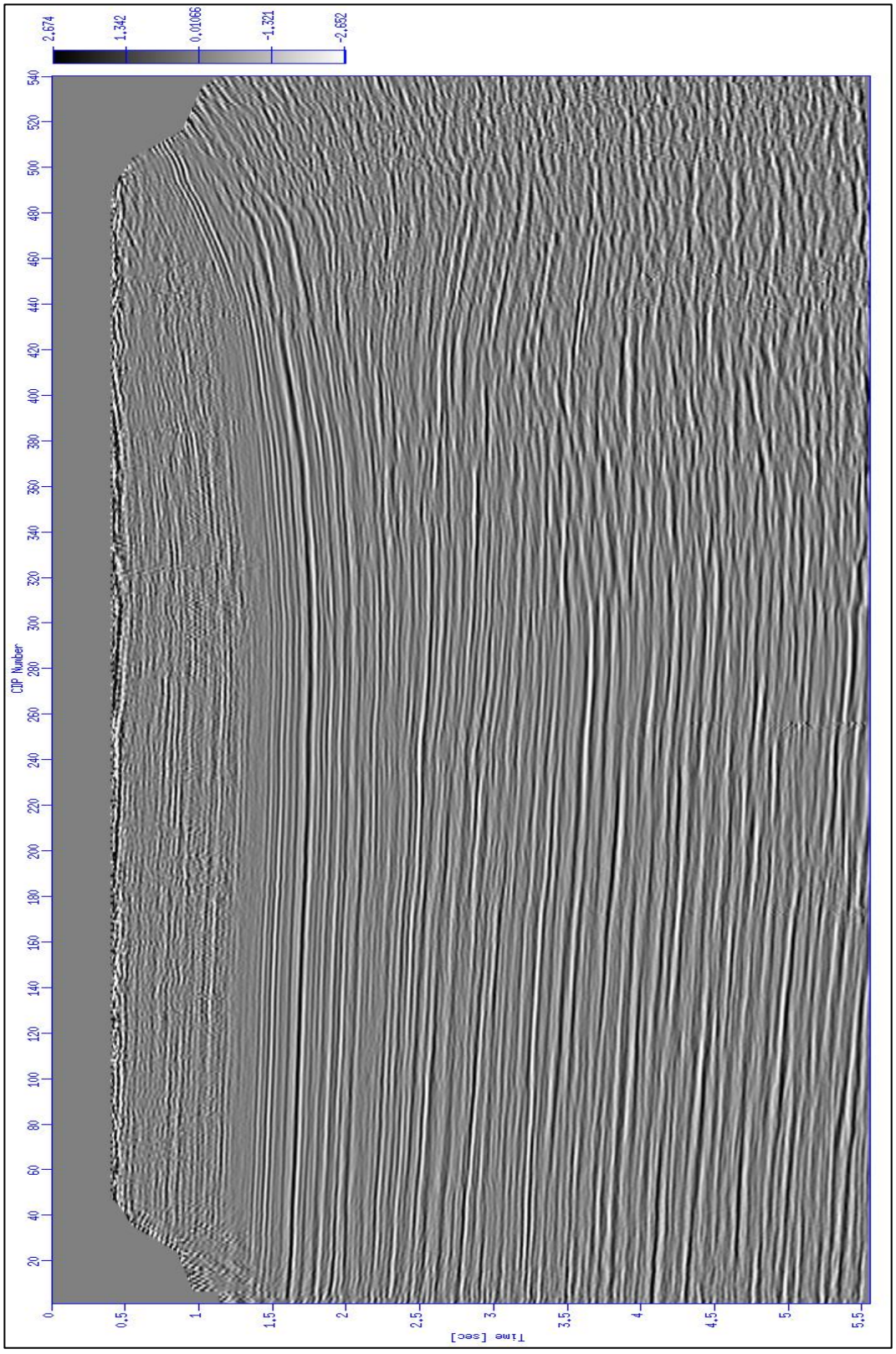


Figure 4.29: Stack section.

4.15 Viewing GPR data

The correct viewing is useful in the processing and interpretation. The GPR data can be displayed as an image or as wiggle traces but the common displaying way is the image as in Fig (4.30).

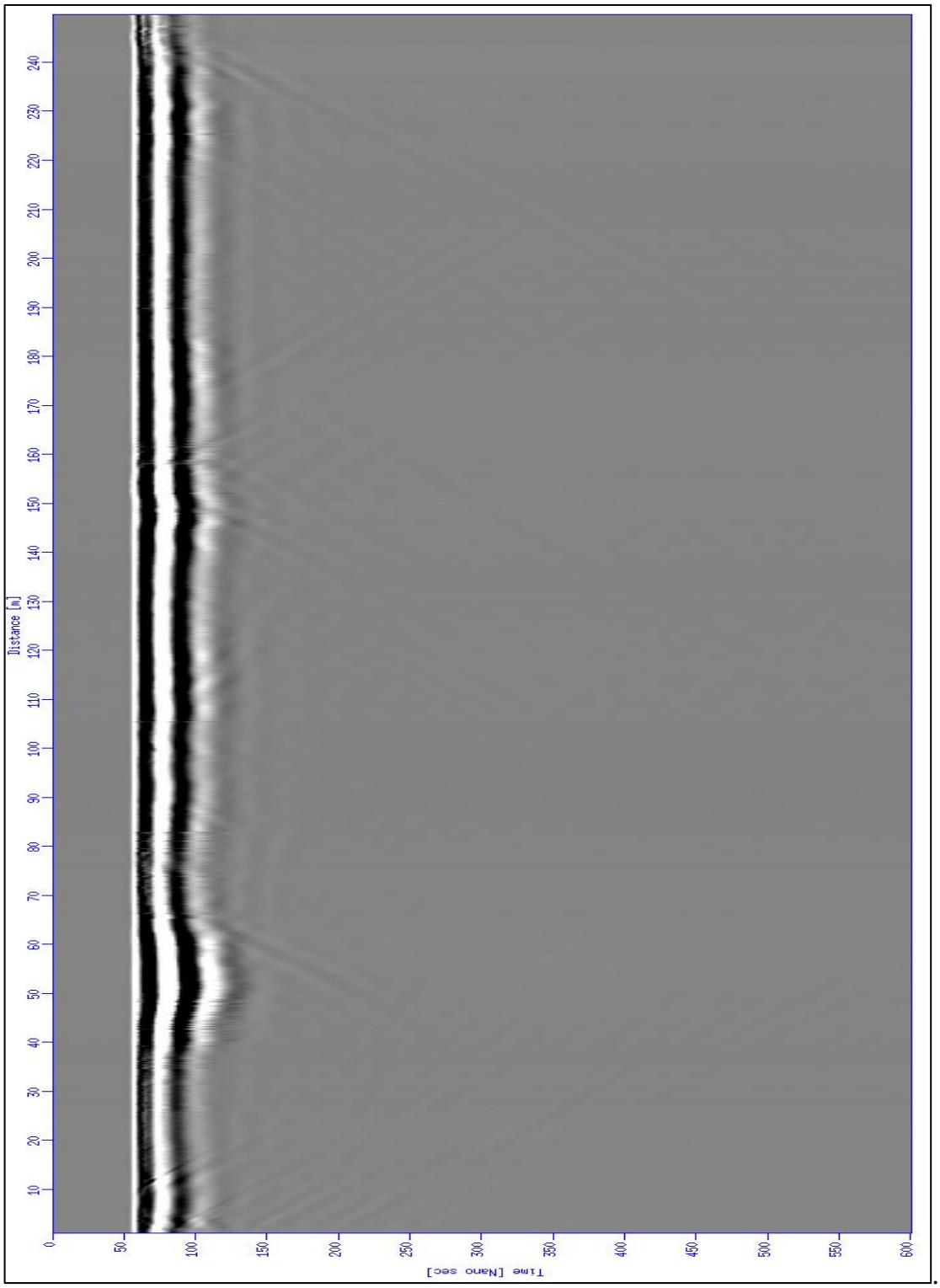


Figure 4.30: converted GPR data in time distance domain.

Chapter Five

Conclusion & Recommendation

5.1 Conclusions

1. The careful check of the data set plays an important role in the all processing procurer.
2. Killing noise traces better than rejection. The rejection lowers the coverage and as result the resolution reduces.
3. Variant traces length affect the deconvolution process. Trace equalization avoid variant traces length effect.
4. Using the shot domain to viewing data is so evident than other domain except in velocity analysis where the sorting should be change to common depth point.
5. The gain values tpow=1 epow=0.5 distribute the seismic energy on all the seismic shot for the studied seismic data in a homogeneous way. While the others restrict their effect at shallow portion, deep portion, upper half and lower half of the shot in an inhomogeneous way.
6. The usage of amplitude spectrum as quality control after gain is efficient.
7. The optimum frequency filter for the data is the bandbass filter with frequency values 5Hz 10Hz 45Hz 50Hz. While others eliminates parts of the reflectors.
8. The frequency- wave number domain give best visualize of noise as slopes in order to determine the filter window.
9. The three pass windows of dip filter better than single bass window which is ruin the reflectors.
10. The best dip filter of the data, with reject slope window values 0.001 and 0.00033 is effective in eliminating the ground roll and air noise and enhancing the reflectors.
11. The usage of autocorrelation window (top view) with value equal to 500 milli-seconds gives clear image about multiple distributions. The usage of autocorrelation as quality control after deconvolution gives clear view of

deconvolution efficiency. Display the side view of autocorrelation window also gives better imagining of deconvolution work.

12. Predictive deconvolution is more efficient in noisy seismic data than spike deconvolution. Applying predictive deconvolution with gap=2000 microsecond and operator length= 3000 millisecond eliminate multiples and increase the vertical resolution for the seismic line of studied data.
13. The intense picking with suitable interval of velocities over all analysis panel give good normal move out correction results by flatting the reflectors.
14. The accurate velocity analysis and stacking are considering as the best filter to attenuate random noise and improve signal to noise ratio.
15. The ability of software to conversion and preparing of GPR data.

5.2 Recommendations

1. Using seismic UNIX package as a foundation for seismic data processing teaching courses and academic research in all Iraqi universities.
2. Using seismic UNIX package for processing ground penetration radar and sonar data.
3. Using seismic UNIX package as signal processing tool in non-geophysical or geological academic departments.
4. Proper design of seismic survey and field quality control to avoid bad or missing shots and noisy traces or different length traces.
5. Applying other frequency filter's types like Gabor and Butterworth.
6. Applying radon or (tau-p) filters to remove multiples.
7. Applying random noise attenuation before and after stack.
8. Compute velocities using other velocity analysis methods.

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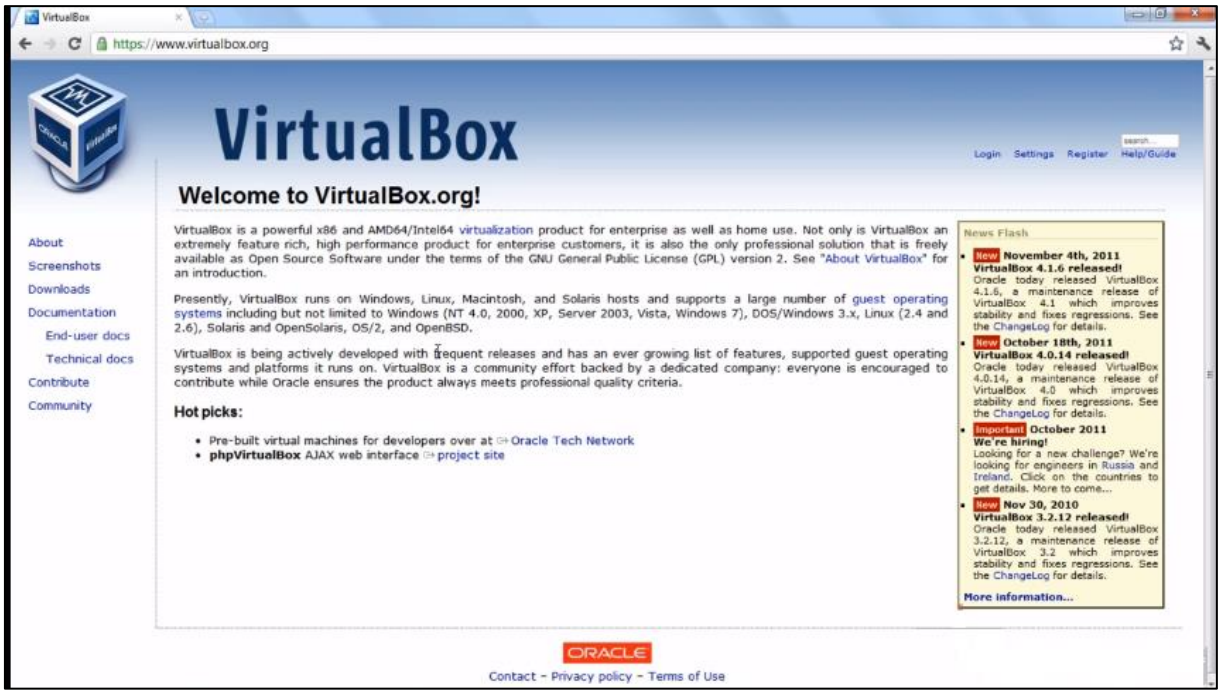
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Appendix A

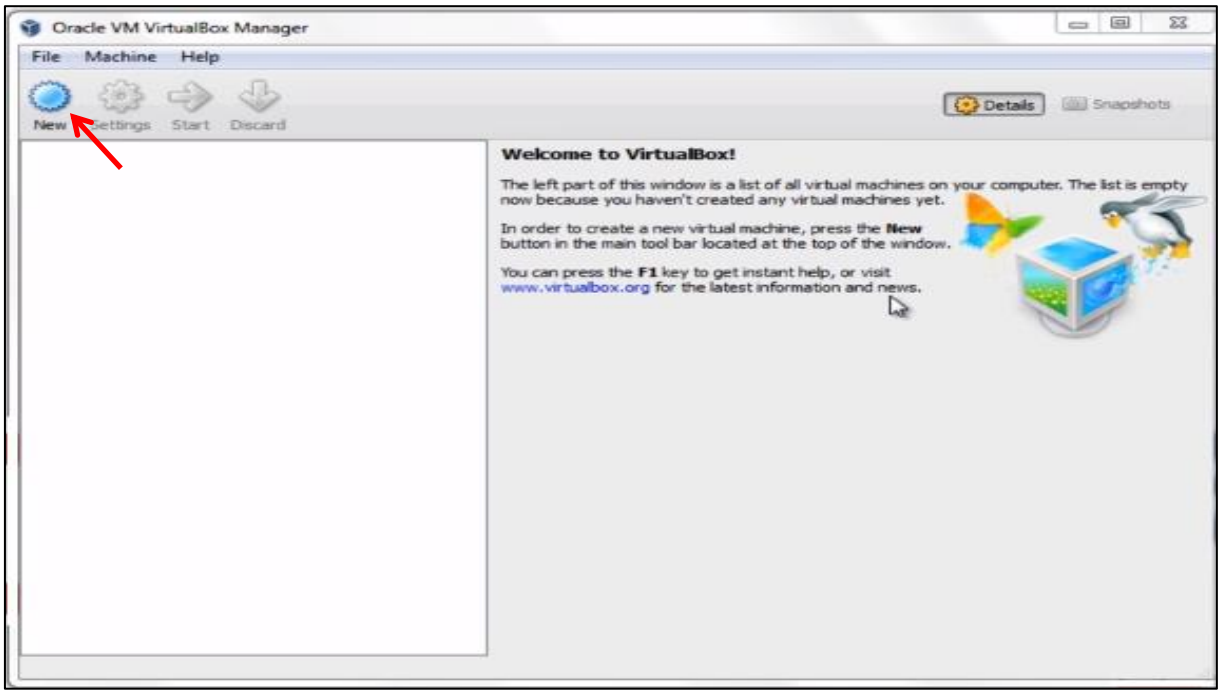
VirtualBox preparations for linux instillation.

1. Install VirtualBox on PC from the the VirtualBox website's download page (www.virtualbox.org) . Choose download from the right. As in A.1.



A.1: VirtualBox website page.

2. Launch VirtualBox from the Windows Start menu Click on New option to create a new virtual machine.



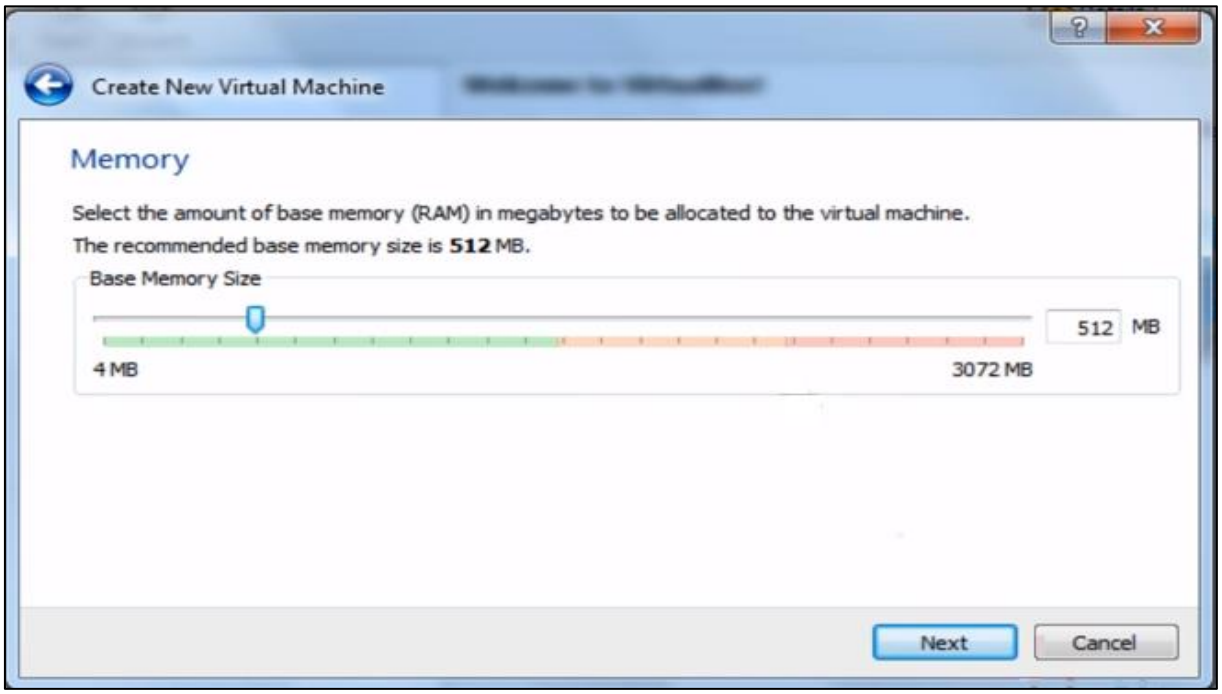
A.2: VirtualBox straining window.

3. New window will appear. Choose virtual machine name and operation system type and version then click next. As in A.3.



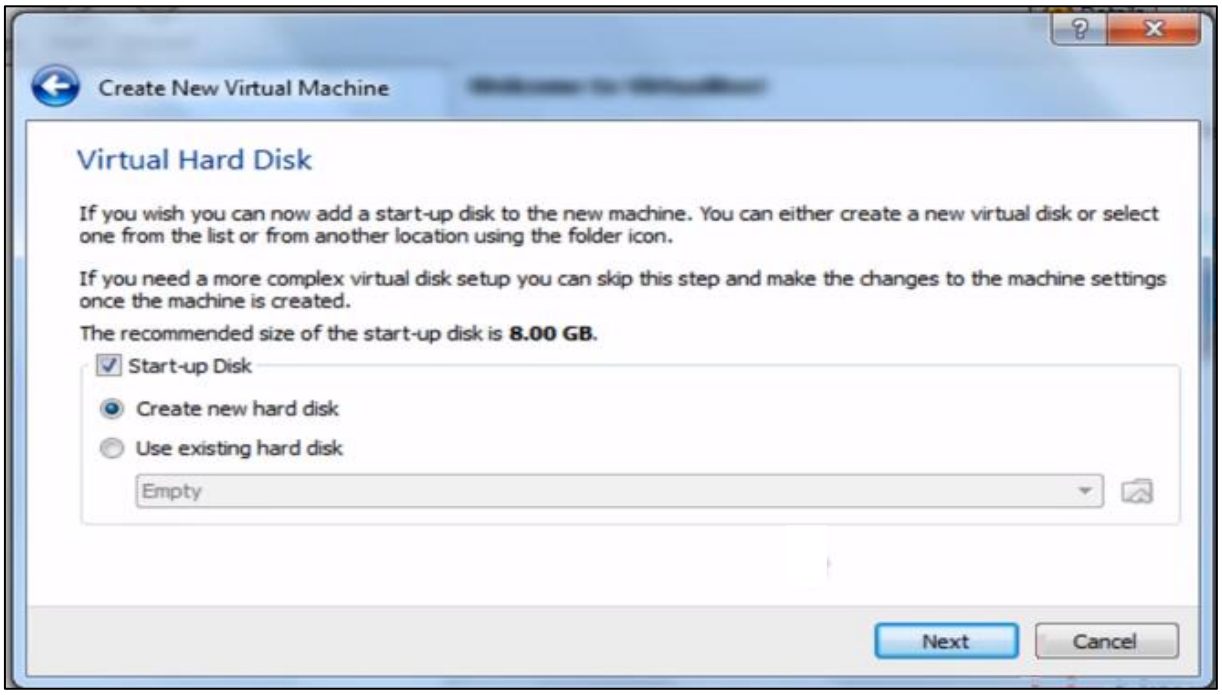
A.3: window to choose VirtualBox name and operation system type and version.

4. Specify the amount of base memory (RAM) in megabytes for the new virtual machine then click next. As in A.4.



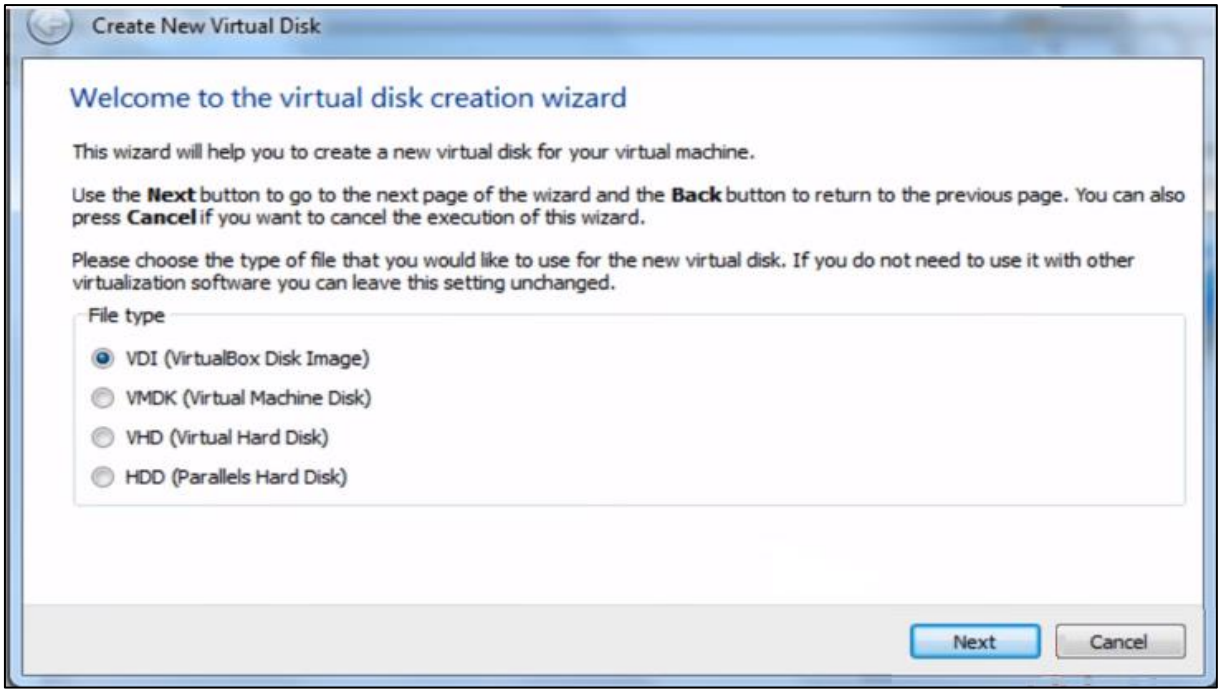
A.4: Window of memory.

5. Create Hard Disk for virtual machine and specify it is size then click next. As in A.5.



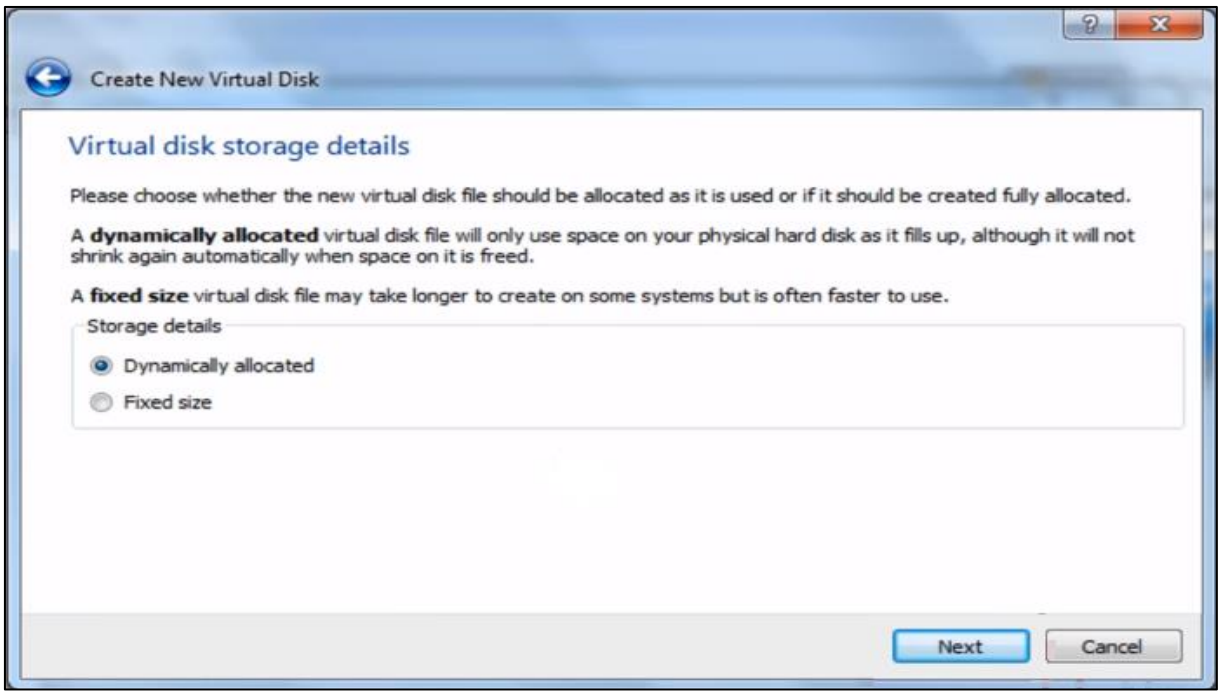
A.5 : Create hard disc.

6. Choose the type of file that I will use for new virtual disk. (in this case choose VDI option or VirtualBox disk image) then click next. As in A.6.



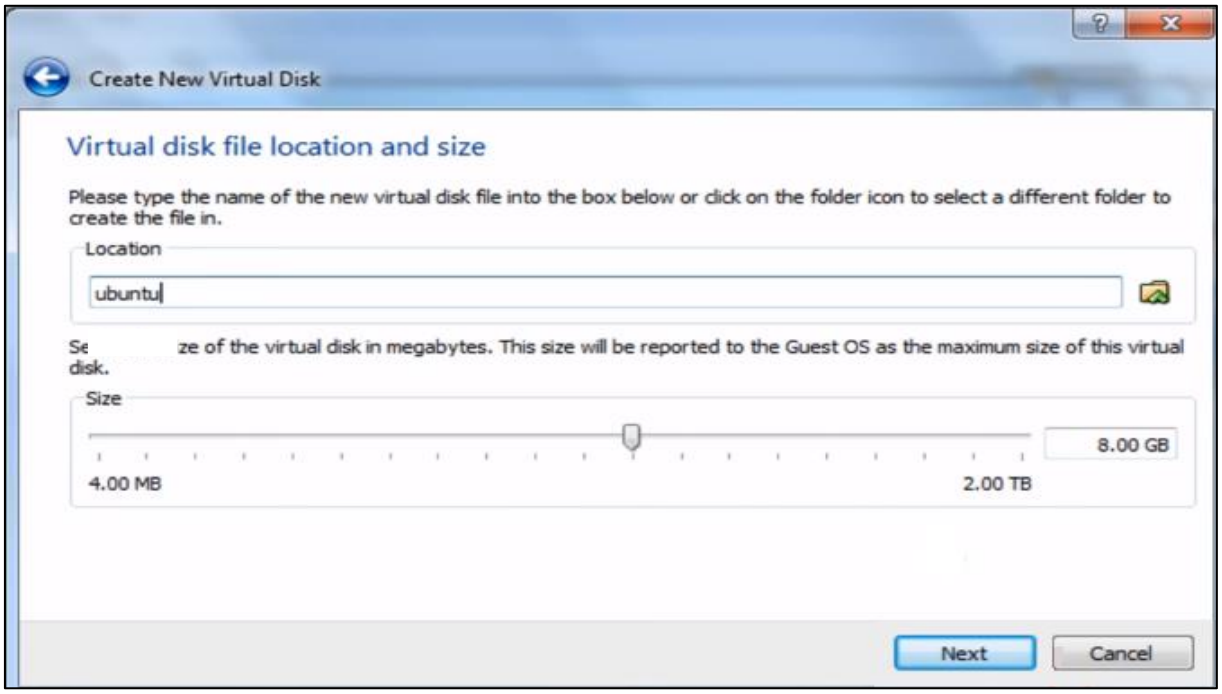
A.6 : Hard disc types.

7. Choose Virtual disk storage type then click next. As in A.7.



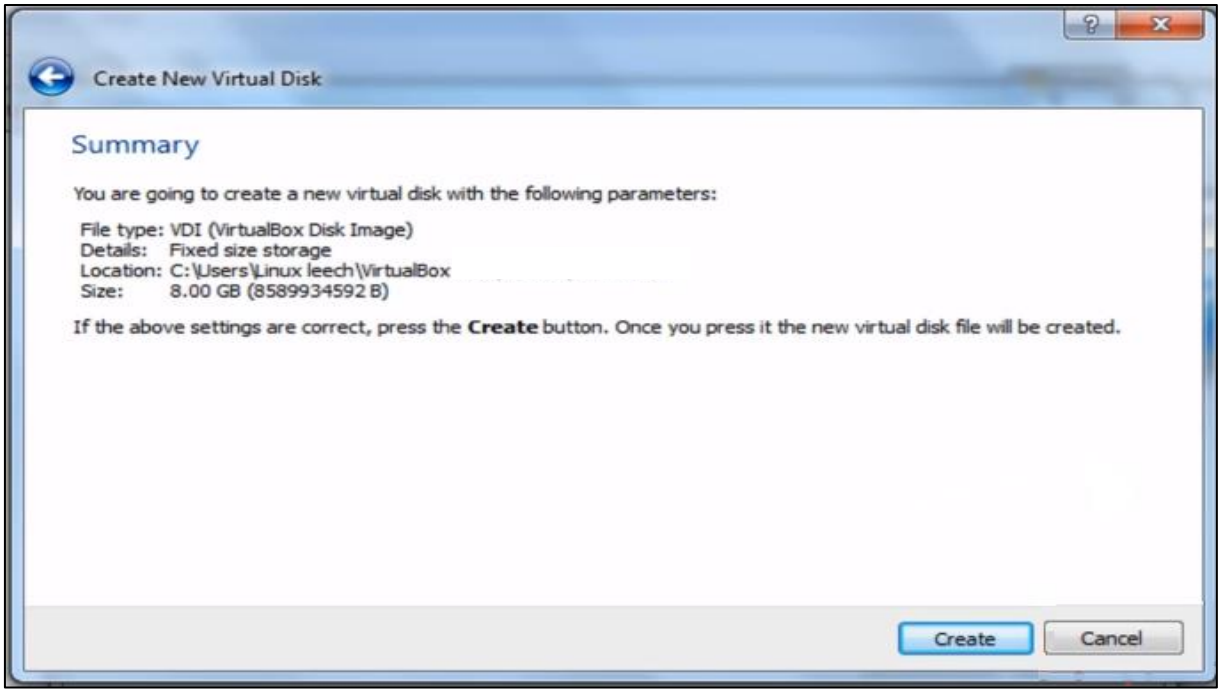
A.7 : Memory type.

8. Specify Virtual disk location then click create. As in A.8.



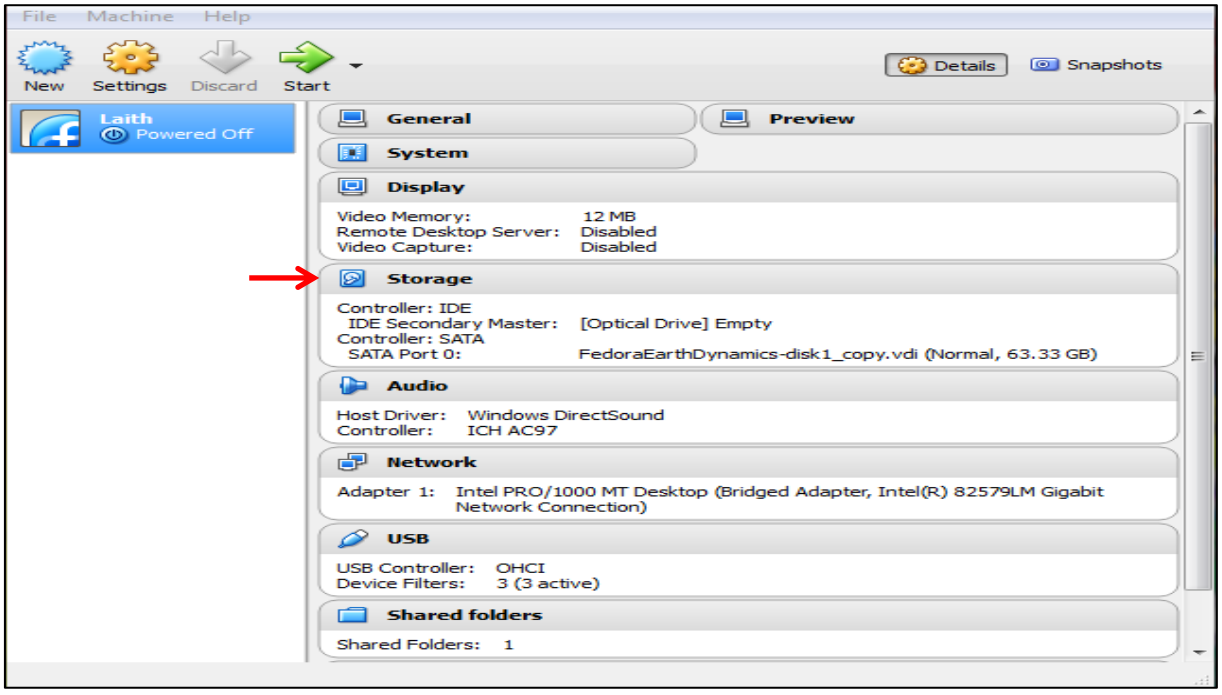
A.8 : Disk size and location.

9. At this stage all your chosen option will be summarized in the window so that you can ensure about it. If you are sure about your options press “Creat” to create new VirtualBox but without operation system in it. As in A.10.



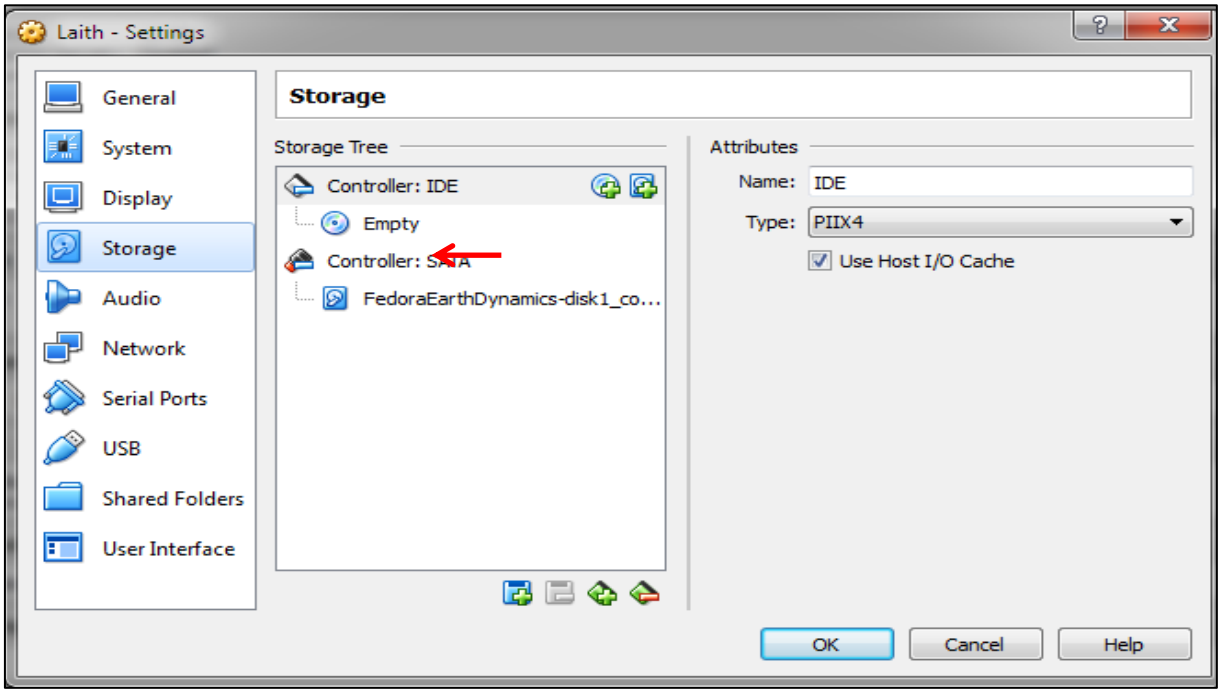
A.10 : Information of new VirtualBox in order to creation.

10. Choose Storage option from starting window. As indicated by the red arrow in A.11.



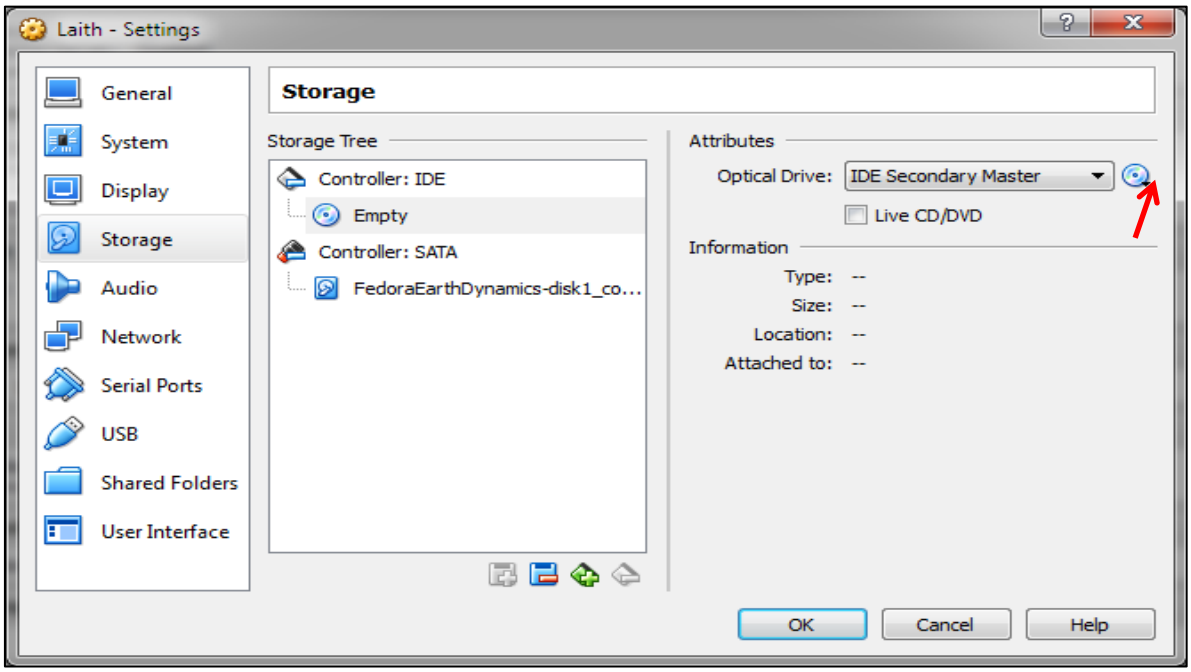
A.11 : Starting Window.

11. Click Empty disk label from Storage Tree sub window. As indicated by the red arrow in A.12.



A.12 : Storage tree sub window.

12. Click on Disk Label in the Attributes to get the option of (Choose a virtual CD/DVD disk file) then click on it. So the virtual machine recognize the downloaded OS. As indicated by red arrow in A.13.

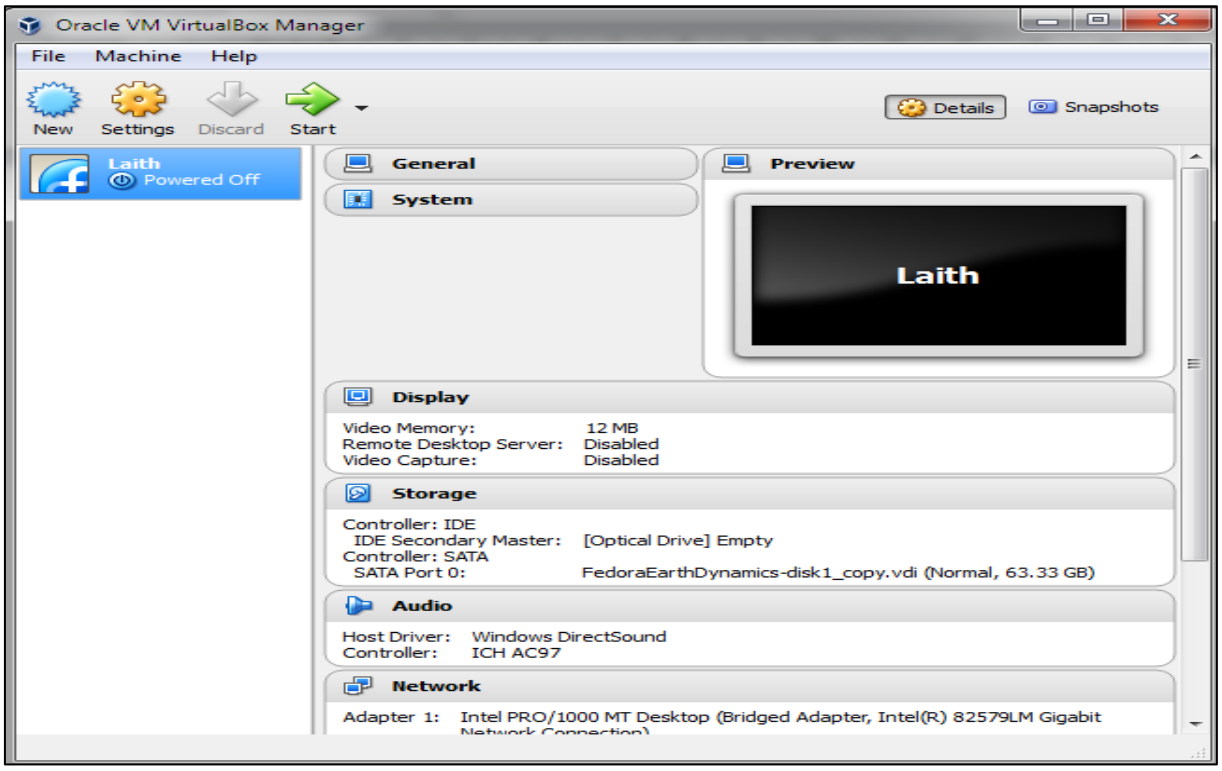


A.13 : Storage tree sub window.

Appendix B

Linux installation.

1. Choose Start from VirtualBox Window software. The Fedora linux will boot so installation screen of it appear.

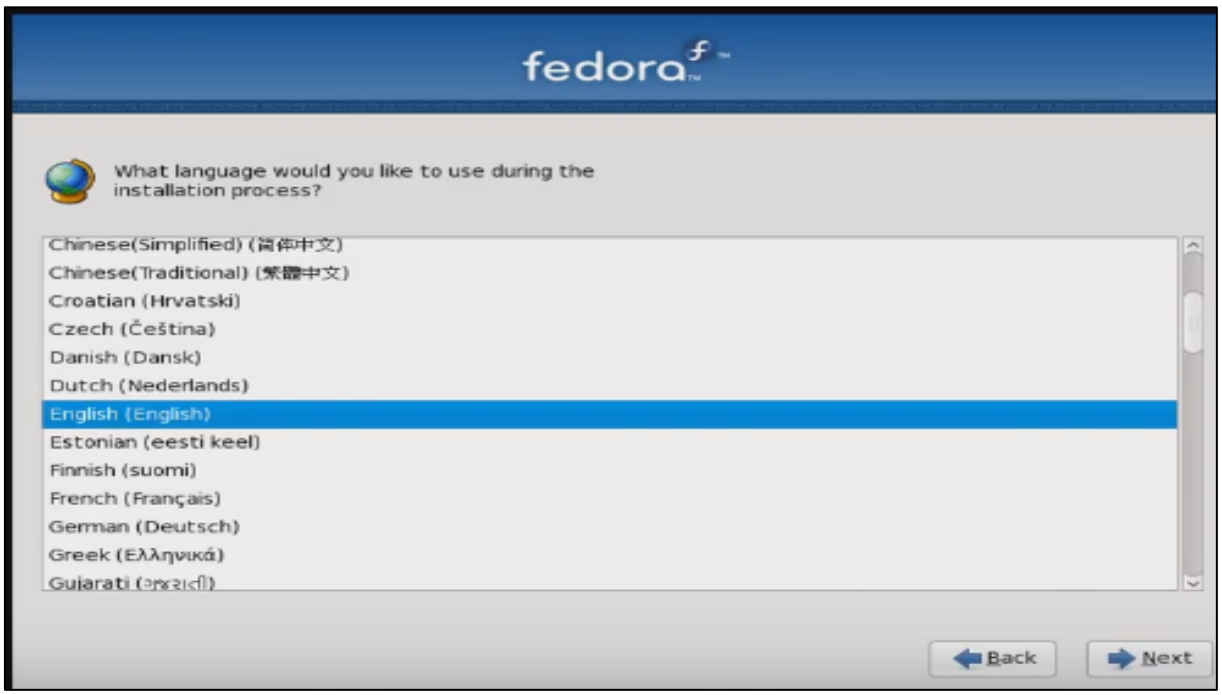


B.1 : Starting window.

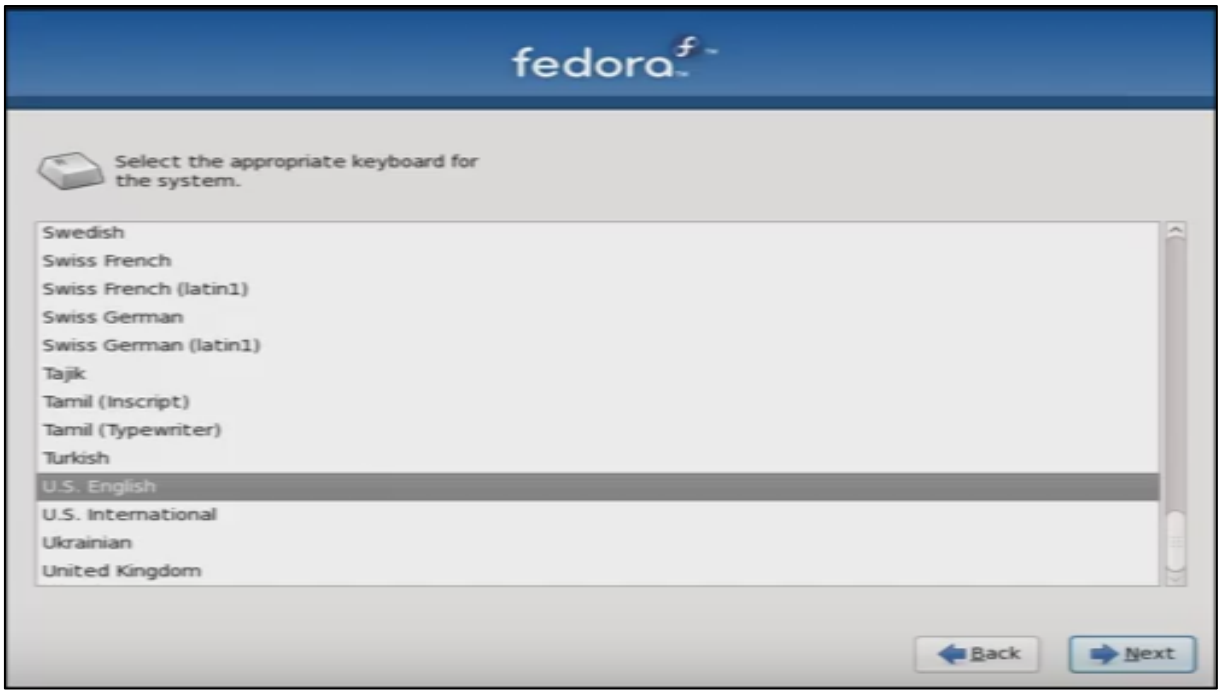
2. Media Test screen will appear click on "skip".



3. Select the appropriate language, then click the "Next" button.



4. Select the appropriate keyboard, then click the "Next" button".



5. Enter the hostname, then click the "Next" button.



6. Select the appropriate time zone by clicking on the nearest city on the map, then click the "Next" button.



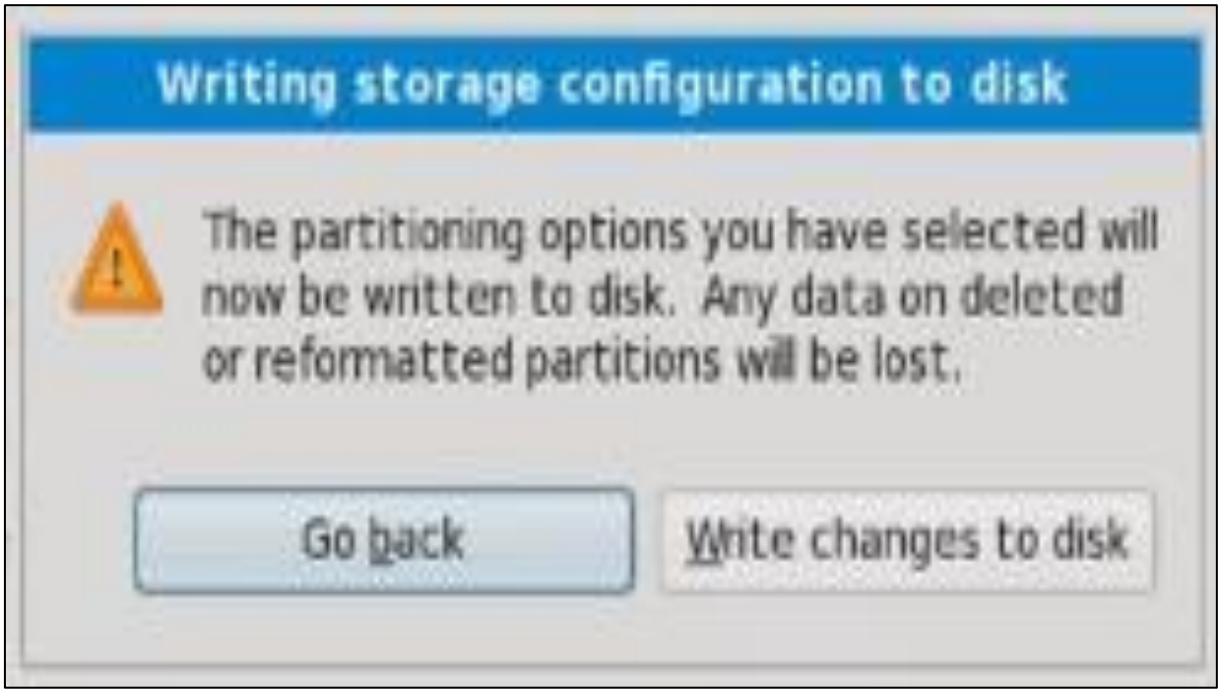
7. Enter the root password, then click the "Next" button.



8. Linux partition utilities screen will appear then choose " use enter drive" option then click "Next".



9. "Writing storage configuration to disk" screen will appear click on "Write changes to disk".



10. Specify the additional tasks would like your system to include support for. Then click "Next".



Appendix C

Seismic Unix installation.

1. Login as “seismic” (not root).
2. Navigate to the directory “/home/seismic”.
3. Make a directory called “su” within the directory “/home/seismic”.
4. Download from ftp://ftp.cwp.mines.edu/pub/cwpcodes/.
5. Don't install as 'root' (the superuser) (It is possible to damage a system's file structure if the install is not done properly.)
6. Download the file: cwp_su_all_xx.tgz and save it in the “/home/seismic/su” directory.
7. Open a terminal and go to the “/home/seismic/su” directory using the command:

cd /home/seismic/su .

8. Uncompress and untar the file cwp_su_all_40.tgz using the command:

zcat cwp_su_all_40.tgz | tar –xvf –

9. Compile the codes using the following command sequence (making sure that you finish executing a command before you try the one after it):

make install

make xtinstall

make finstall

make utils

make xminstall

make mglinstall

المستخلص

استخدم في هذه الرساله برنامج معالجة زلزالي جديد لمعالجة المعلومات الزلزالية. ان كل برامج المعالجة تتشابه بوظيفتها التي هي المعالجه. ان مجموعة اليونكس الزلزالي هي برنامج المعالجه الجديد والتي تكمن حداثتها ليس فقط في الوظائف التي تؤديها بل في فكرة تكوين اليونكس الزلزالي.ان فكرة البرنامج الحر المفتوح المصدر تقدم اول مره للمجتمع الكاديمي للعلوم الجيولوجيه على مستوى العراق في هذه الرسالة.

ان فكرة البرنامج الحر المفتوح المصدر تعني ان لمستخدم البرنامج مطلق الحريه لتشغيل ونسخ وتوزيع ودراسة وتغير وتحسين البرنامج وهذا يساهم في زيادة التعلم المتبادل بيننا عندما تكون المعلومات متوفره و حرية تبادل الافكار تخلق بيئة تعاونية تحل المشاكل التي قد لايمكن حلها بالمجهود الشخصي.

ونتيجة لذلك فان اليونكس الزلزالي يدعى بمجوعة اليونكس الزلزالي بسبب كونه تراكم للفضول العلمي للباحثين في مجال المعالجه الزلزالية والموجيه. هذه الرسالة تمكن الطلاب من استخدام المعالجه الزلزالية للعمليه بينما كانت بالسابق حكرا لمجموعه قليله. في هذة الرسالة استخدمت بيانات محمله مسبقا عولجت باليونكس الزلزالي لزيادة الوضوح والتدرب على المعالجه والبرنامج واستخدام بيانات حقليه للمعالجة.

البدايه كانت في اختبار البيانات بالنسبه للترتيب الحقلي و وجود اوعدم وجود مصادر طاقة مفقودة او تريسات مشوشه التي ازيلت فيما بعد. المعالجة الزلزالية تنجز من خلال اجراء اختبارات تقليدية مثل مجال التردد – طول موجي و التطابق التلقائي والتي تدلنا على الضوضاء المسيطرة وفقا لها نختار محددات مرشح الميل ومرشح عدم التطابق التلقائي. اما المعالجة الزلزالية الاخرى تنجز من خلال اجراء اختبارات تجريبية وتختار القيمه الاكثر ملائمه مثل مرشح التردد و تصحيح التحلل الموجي و تصحيح التحرك للخارج العادي. والكتم ايضا طبق للبيانات. اظهر اليونكس الزلازالي مرونة عالية في التحويل والتحضير لمعالجة مستقبلية للبيانات غير الزلزالية مثل بيانات الاختراق الارضي. النتيجة النهائيه كانت هي لمقطع المكثف بدقة عالية والذي يدل على كفاءة اليونكس الزلزالي و اسلوب المعالجة المتبع ونتيجة لهذا فان اليونكس الزلزالي قابل للتعلم من قبل الطلبة العراقين.

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تطبيقات منظومة اليونكس الزلزالي في معالجة البيانات الزلزالية و رادار الاختراق الارضي

رسالة مقدمة الى

كلية العلوم - جامعة بغداد

كجزء من متطلبات درجة الماجستير

في علم الأرض-الجيوفيزياء

من قبل

ليث فهد تركي

بكلوريوس علم الارض
2012

اشراف

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