SEISMIC PROCESSING OF UMIAT BASIN, ALASKA

A DISSERTATION

Submitted in partial fulfillment of the
Requirements for the award of the degree
Of

INTEGRATED MASTER OF TECHNOLOGY

In

GEOPHYSICAL TECHNOLOGY

By

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MAY, 2019

CANDIDATE’S DECLARATION

I hereby declare that the work which is has been presented in this dissertation entitled, “**Seismic Processing of Umiat Basin, Alaska**” in partial fulfillment of the requirements for the award of the degree of **INTEGRATED MASTER OF TECHNOLOGY** in **GEOPHYSICAL TECHNOLOGY**, submitted in the Department of Earth Sciences, Indian Institute of technology, Roorkee, is an authentic record of my own work carried out under the guidance of **Prof. Sagarika Mukhopadhyay**, Department of Earth Sciences, IIT Roorkee, during the period of January 2019 to May 2019.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma of this institute or any other university/institute.

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CERTIFICATE

This is to certify the work presented in this thesis entitled "**Seismic Processing of Umiat Basin, Alaska**" submitted by Mr. Rachit Rajan Bagade to Indian Institute of Technology, Roorkee, India, in partial fulfillment of the requirements for the award of the degree of **INTEGRATED MASTER OF TECHNOLOGY in GEOPHYSICAL TECHNOLOGY** is a record of bona fide original work carried out by his under our supervision during the academic year 2018- 2019.

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Abstract

Seismic survey plays an important role in exploration of oil and gas. It stands miles ahead of various other methods that are used to resolve the interior of the earth in terms of expenditure as well as accuracy, resolution and penetration.

The main aim of seismic survey is to produce detailed images of subsurface of the earth resembling with the geological structure beneath the Earth's surface and use this information for exploration of oil and gas. It is a method of prospecting that uses the principles of seismology to estimate the properties of the Earth's subsurface from reflected seismic waves. This method is used for a detailed study of the subsurface of Umiat Basin.

Umiat basin is located in North Slope, Alaska and has Prudhoe Bay Oil Field nearby making this basin a prospect for oil and gas accumulation. The stratigraphy of the basin consists of many shale sequences like Kingak Shale, pebble shale unit, Hue Shale and many more which can act as the source rock for oil and gas generation. Moreover, the tectonic and orogenic setting of the basin is suitable for migration and trapping of oil. Thus, five profiles of seismic data were chosen for processing in Paradigm software to get a zero-offset section of each of the profile.

For processing of seismic data, many of the processes were carried out including editing, muting, geometry definition, ground roll removal, amplitude scaling, f-k filtering and deconvolution to remove the noise as much as possible and get the best out of the given data. Next, Velocity picking was done in CDP domain in order to get stacked section. Finally, Migration was carried out to remove diffraction hyperbola and multiples as well as to translate the reflection events to their original position. Some touch-up of data was done using post-processing modules. Zero-offset sections were obtained after carrying out all the above mentioned processes. The sections show that there are indeed some of anticlinal structures which can act as a trap to oil.

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Chapter 1: Introduction

Seismic method is one of the many methods that use the basic fundamental principle of propagation of acoustic waves through solid earth. From observing Earth's oscillation at very long period for several hours to studying rock physics at ultrasonic range, a wide spectrum can be covered by focusing on the frequency to observe different phenomena. Spectrum is shown in Figure-1.1 given below

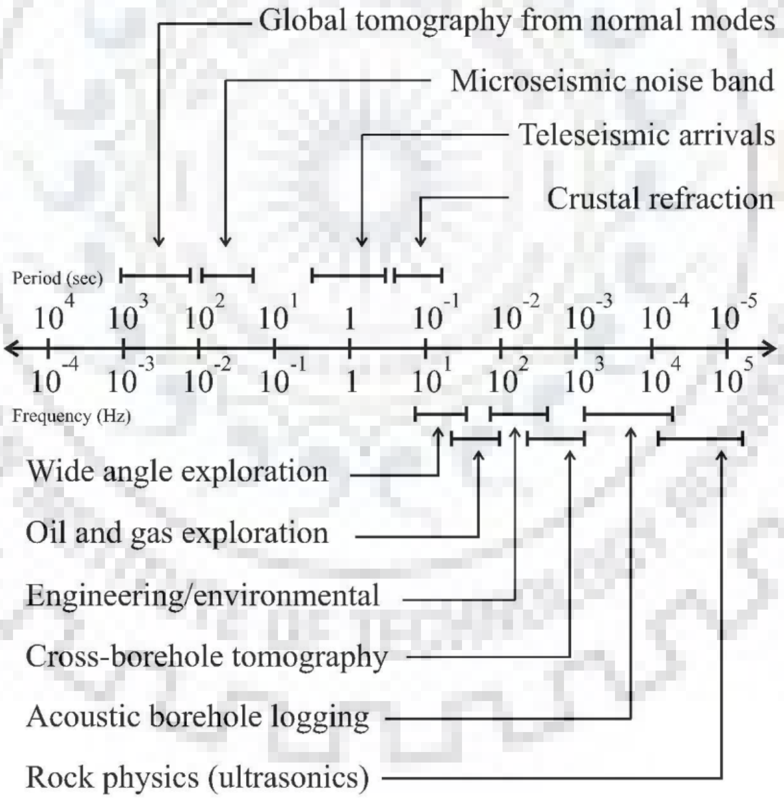


Figure 1.1: Frequency/Period for different methods (acoustic signal) (Pratt, 2005)

Seismic methods, primarily used for petroleum exploration, are also used for widespread applications including groundwater exploration, mineral exploration and many more. As the frequency increases, depth of measurement decreases resulting in varying applications (Telford, 1993). For oil and gas exploration, low frequency is used to observe the subsurface up to a depth of few kilometers.

The basic technique used in seismic method is by generating acoustic waves with the help of artificial sources like dynamite or airgun, in case of marine survey, and measuring these waves by series of geophones laid down in an orderly pattern (mostly along a straight line). The data is mostly recorded in digital form and processed to remove noises to get the original signal. By analyzing the original signal, valuable information on subsurface can be obtained from the variation in amplitude, frequency, phase and wave number which can help in determining possible structures wherein oil and gas might be found.(Sheriff,1995)

There are two types of surveys which are conducted under seismic method (Figure 1.2):

1. Reflection survey- Waves travel through subsurface and at some interface are reflected back.
2. Refraction survey- Waves travel through subsurface and at an interface it travels along that interface to get refracted back

For both these types of surveys, travel time of the wave primarily depends on the physical properties of the rock through which the wave is travelling and the depth of interface from which the wave is reflected/refracted back (Telford, 1993). For oil and gas exploration, reflection survey is used for the most part and refraction is used to find Low Velocity Layer (LVL) to detect low velocity zones present in the area (Upadhyay, 2004).

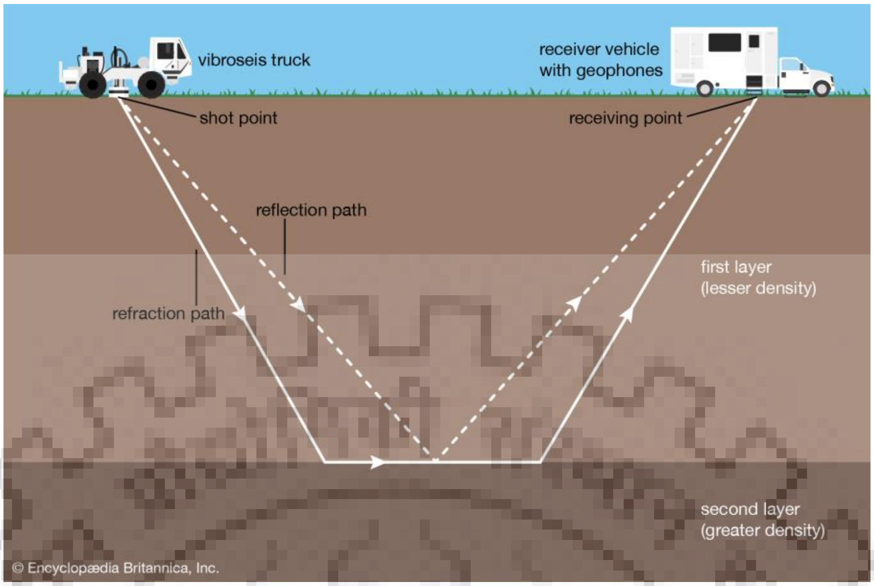


Figure-1.2: Reflection and refraction in seismic survey (Encyclopedia Britannica, 2005)

There are various types of the surveys which can be conducted:

- 2D survey- It gives a cross-section image of the sub-surface in a particular direction (inline direction). It is preferred that reflected energy should correspond to the event in subsurface which in case of 2D may not always be true as the reflected energy may correspond to events dipping out of the section. This causes difficulties with the interpretation and may mean that crossing 2D lines do not tie (have similar events at the same time).
- 3D survey- 3D surveys give a three dimensional view of the subsurface and overcome the limitation of 2D surveys. 3D survey can be thought of as a series of closely spaced 2D lines giving complete spatial coverage over the target area.
- 4D surveys- Time-lapse or 4D surveys are 3D surveys carried out at a time interval in a producing reservoir to monitor the changes in reservoir parameter such as porosity, pressure, saturation etc. as oil and gas production is carried out (Lumley, 1995 ; Yilmaz, 2001, Redshaw, 2012).

For the present work, we will be working with 2D seismic data.

1.1 Seismic Data Acquisition

Seismic acquisition system consists of the following elements:

- Energy source
- Energy receiving unit, i.e. geophone
- Digital recording system

Artificial or active energy sources are used for acquiring seismic data wherein it creates a localized region within which the sudden release of energy occurs leading to a rapid stressing of the surrounding medium (Keary, 2002). Energy sources are of two major types-

- Land
    - Explosives
    - Mechanical vibrator (vibroseis)
    - Buried primacord
    - Land airgun
- Marine
    - Airgun
    - Steam gun

The detectors used in seismic prospecting are electromechanical transducers that convert a mechanical input into an electrical output. The receiver system consists of geophones on land and hydrophones for marine seismic data acquisition (Keary, 2002). During a seismic survey, a cable with receivers attached to it at regular intervals is laid out along a line or towed behind a ship (in marine surveys).

The data is recorded in common shot gather format. When the traces of the gather come from a single shot and many receivers, it is called a common shot gather. Various other types of gathers are given in Figure-1.3

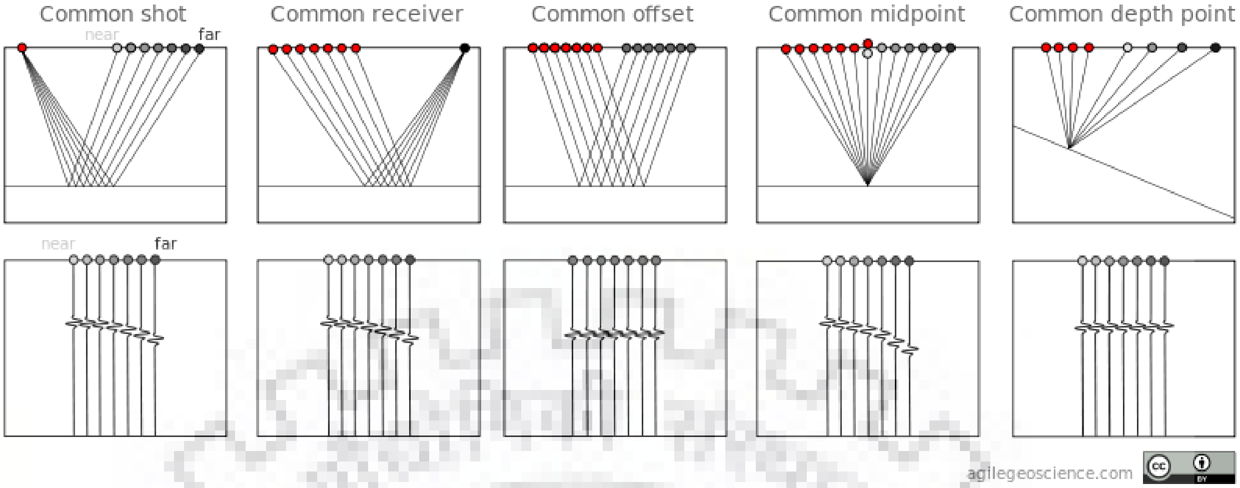


Figure 1.3- Different source receiver combinations (Source-https://goo.gl/VmzPTU)

The basic aim of data acquisition is to record a signal having high signal-to-noise ratio and a broader bandwidth for better resolution to fulfil the geological objectives. These objectives can be achieved by attenuation of noise and improvement of signal strength at the stage of data acquisition and data processing. Not all, but some of the noises can be attenuated during data acquisition and some at the stage of data processing. Thus, it is important to devise strategies and survey planning before conducting the survey. The approach to get data with high signal-to-noise ratio is to optimize the basic acquisition parameters and reduce all possible errors while recording the data on field and also effectively reducing the cost of the operations. Moreover, the surface conditions play a very important role in defining the quality of data collected. (Cordsen, 2000)

1.2 Seismic Data Processing

Seismic data processing is a sequence of mathematical operations which is carried out to extract the useful information from the set of raw seismic data recorded in field. It is a computational analysis of recorded data to create a subsurface image and estimate the distribution of properties. Seismic processing facilitates better interpretation because subsurface structures and reflection geometries are more apparent. It provides the interpreter with a seismic image which is quite akin to a geological section. There are three major steps involved in processing of seismic data (Yilmaz, 2001)-

- Deconvolution
- CMP stacking
- Migration

Other processing steps include analysis of velocities and frequencies, static corrections, deconvolution, normal move out, dip move out, stacking, and migration, which can be performed before or after stacking. Basic theoretical workflow of processing of seismic data is given in Figure-1.4 below-

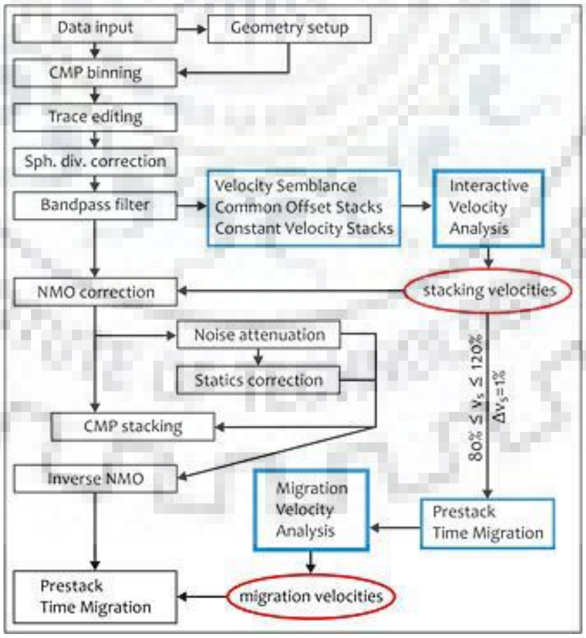


Figure-1.4- Processing of seismic data workflow (Yilmaz, 2001)

Deconvolution is a process which compresses the basic seismic wavelet which in turn increases the temporal resolution of the data. Moreover, the process increases the bandwidth of the wavelet and can also be used to attenuate ghosts, instrument effects, reverberations and multiple reflections.

Seismic data during a seismic survey is recorded in shot receiver coordinate while the processing of the data is done in midpoint-offset coordinate. Thus, to bring the data from shot-receiver format to midpoint-offset format, the data is sorted to CMP (common midpoint) gather. According to the field geometry, each gather is assigned a midpoint with the help of locations (coordinates) of shot and receiver as can be seen in Figure-1.5. Assigned gathers of the each midpoint is then grouped together to form CMP (common midpoint) gather. These gathers are summed together to form a stack section.

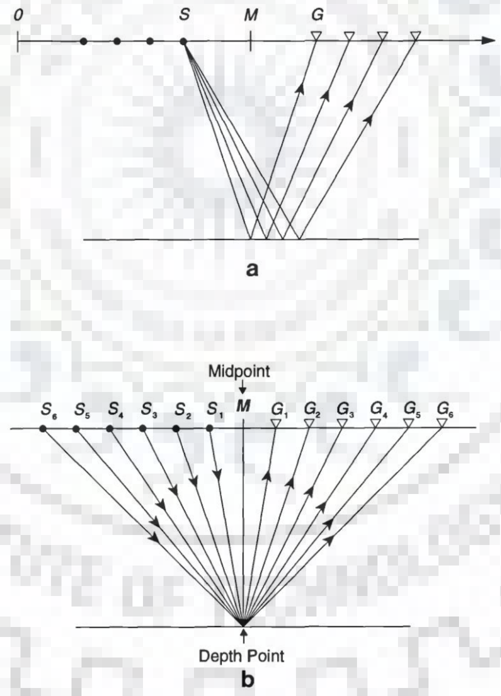


Figure-1.5-a. Shot gather from a source. b. Corresponding CMP gather through sorting (Yilmaz, 2001)

Stacking is a very important and robust step in the processing of seismic data. Stacking helps in increasing signal-to-noise ratio. (Yilmaz, 2001) Stacking gives a seismic time section which would have been obtained if seismic source and receiver both are at the same location. (Lamer, 1992)

Prior to migration, seismic data points are oriented with respect to the common midpoint where it is assumed that the interfaces in the subsurface are non-dipping. Migration involves repositioning of these data points to their original location associated with the reflectors, while also collapses the diffraction hyperbolas.

Events with conflicting dips require an additional step – dip-move out (DMO) correction prior to CMP stacking. It can be avoided in case we go for pre stack time/depth migration. In the present work, we used 2D pre stack time migration (Yilmaz, 2001).

1.3 Seismic Data Interpretation

The next step after processing the data is to analyze and interpret the generated section obtained after migration. While carrying out interpretation, it is important to keep in mind that the given seismic trace may not be associated with the reflector in the subsurface. Often a reflection is characterized with two troughs (or crests) in a single trough over a few traces (Dobrin, 1960). Such type of waveforms may be associated with geology but more often; these are due to noises and distortions. As a result, resolution of the seismic measurements is key component to keep in mind while interpreting the section.

The main focus when interpretation is done is on structures where the oil and gas may accumulate namely-

- Structural traps - These traps are formed due to tectonic processes. Fault, fold and diapirs are some examples of these traps.
- Stratigraphic traps -These traps caused by depositional caused by depositional morphology or morphology or diagenesis. Examples include pinchout (Bjorlykke, 2010)

Structural interpretation includes well-to-seismic tie, horizon interpretation, fault interpretation and generation of time-relief and time-structure maps (Dobrin, 1960).

Chapter-2: Geological and Tectonic Settings

Study area for the seismic data for which the processing is done is Umiat Basin which comes under Alaska, United States of America. Umiat is located in North Slope Borough near Coleville River 140 miles southwest of Deadhorse in the Arctic Circle. The area is not accessible by road or rail, only by air or river. Area is characterized by low-relief, treeless hills south of the Arctic coastal plain. As with any Arctic sub-region, this area also does not have a permanent human settlement. (Geographic Names Information System. USGS, 1981, Herriott, 2018)

The study area extends in the eastern sector of National Petroleum Reserve–Alaska (NPRA), about 180 kilometers south of Prudhoe Bay oil field, in the North Slope of northwestern Arctic Alaska. The NPRA is bound by Chukchi Sea westward, by the Beaufort Sea northward, by the Colville River eastward and by the Brooks Range southward. The NPRA is located within the foreland basin ahead of the Brooks Range, which is known as the Colville Trough. The Umiat Basin represents a minor sub- basin of the Colville Trough.as can be seen in Figure-2.1 (Bird, 1981)

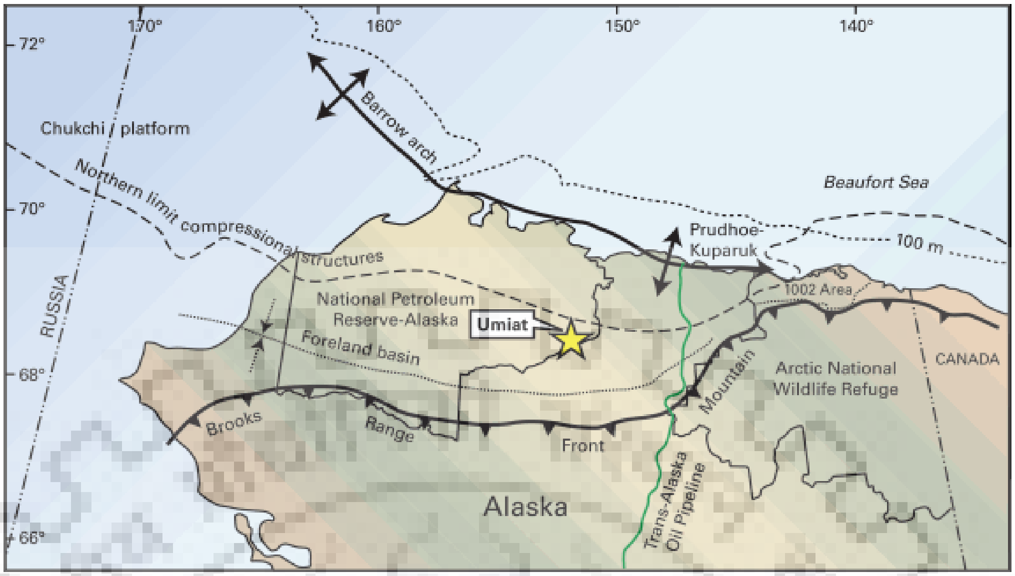


Figure-2.1- National Petroleum Reserve–Alaska (NPRA) with bordering geological structures (Alaska Geological Survey, modified by Bird, 1992)

2.1 Stratigraphy

There are three major mega-sequences across Arctic Alaska deposited over basement known as Franklinian basement which is metamorphosed:

- Ellesmerian (Carboniferous-Jurassic)
- Beaufortain (Jurassic-Cretaceous)
- Brookian (Cretaceous to Cenozoic) (Hubbard,1987)

The Ellesmerian sequence is further divided into Upper, Middle and Lower. Upper consists of the Shublik Formation, the Sag River Sandstone and drift sequence while Middle is made up of the Endicott, Lisburne and Sadlerochit groups, and Lower is filled with synorogenic fill which crops out in the Brooks Range. The Ellesmerian sequence is composed of Mississippian to Triassic marine carbonate and nonmarine to shallow marine siliciclastic strata deposited on a passive continental margin. (Hubbard, 1987).

The Beaufortian sequence is divided into four sequences which are-

- Sequence K1 (Lower-Middle Jurassic)
- Sequence K2 (Oxfordian-Kimmeridgian)
- Sequence K3 (Valanginian).

- Sequence K4 (Hauterivian)

The Beaufortian sequence, in whole, is a complex of Jurassic to Lower Cretaceous siliciclastic sediments recording erosional and depositional effects of rifting associated with the opening of the Arctic Ocean Basin.

The Brookian sequence consists of three fundamental depositional cycles: the Nanushuk–Torok, the Tuluvak–Seabee, and the Prince Creek–Schrader Bluff–Sagavanirktok systems (Decker, 2007). The Brookian sequence is primarily composed of Cretaceous to Tertiary synorogenic siliciclastic sedimentary deposits derived from the Brooks Range orogenic belt and deposited in deep marine to non-marine systems in the Colville foreland basin and on the continental margin north of the Barrow arch as can be seen in Figure-2.2 (Hubbard, 1987).

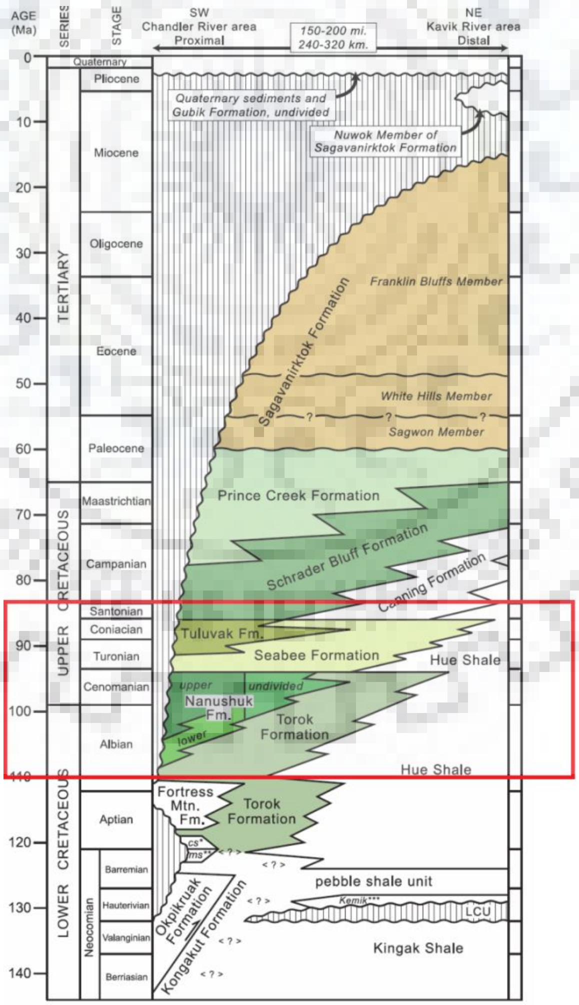


Figure-2.2- Colville foreland basin chronostratigraphic column. The stratigraphy that crops out in the Umiat–Gubik area is outlined in red (after Mull and others, 2003)

In Early Cretaceous, Barrow Arch rift was uplifted which led to subaerial exposure and erosion of older strata creating Lower Cretaceous Unconformity (LCU) which can be observed in Figure-2.3 (Bird, 1985; Hubbard, 1987). LCU varies widely due to the difference in the erosion rates, even is disconformable in most places, but angular discordance is evident in cross-sections traversing the Barrow Arch. (Cole, 1997)

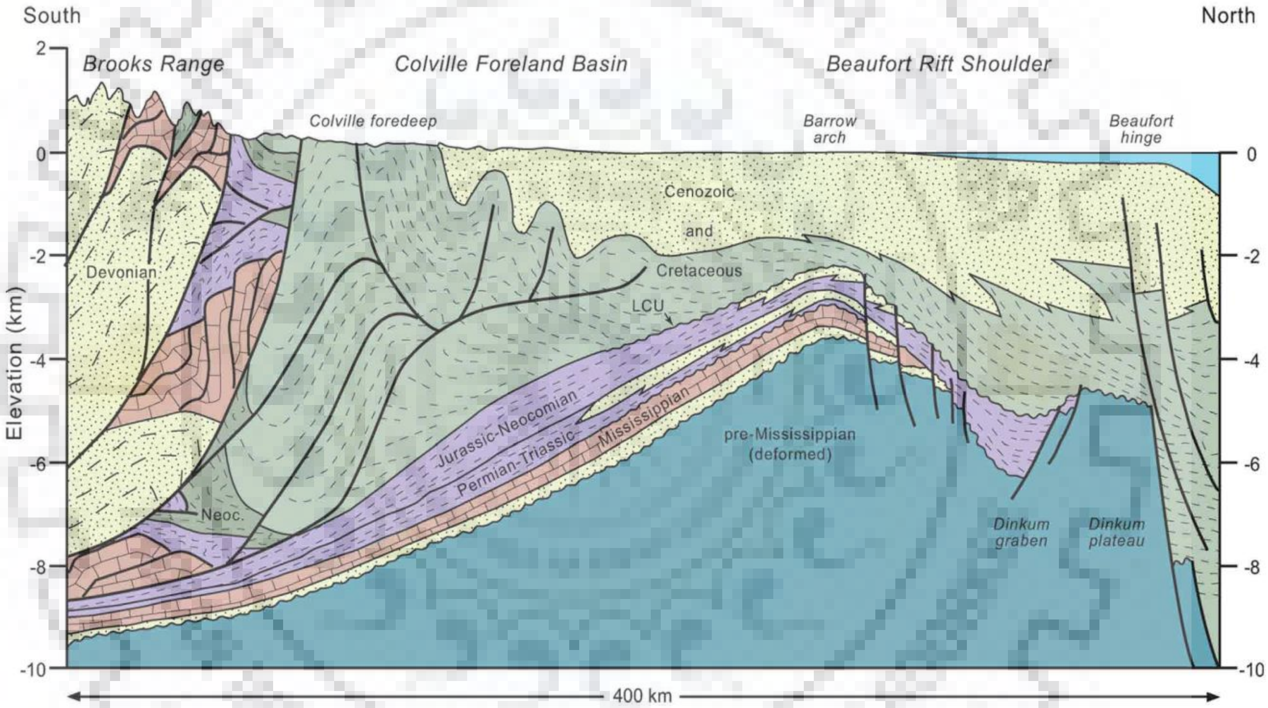


Figure-2.3- Schematic cross section of the Brooks Range and North Slope from Bird and Houseknecht (2011; modified from Bird and Bader, 1987). Abbreviation: LCU—Lower Cretaceous unconformity (after Herriott, 2018).

Under Cretaceous strata of Colville Trough lies Late Devonian-Triassic sediments which are deposited on a passive rift extended from present day Arctic Alaska and northwest Canada offshore to the Chukchi and Beaufort Seas. These sediments are caused due to northern tectonic high. (Bird, 1981).

Many of the source rock are of Mesozoic age and are found in various formations in subsurface of the study area. These formations include Shublik Formation, Kingak Shale, pebble shale unit, Hue Shale, and Torok Formation (Herriott, 2018). Petroleum genesis in central Brooks Range is as a result of tectonic burial, sedimentation and deformation of Brooks Range fold and thrust belt during mid- Cretaceous to Paleocene time (Bird, 1981).

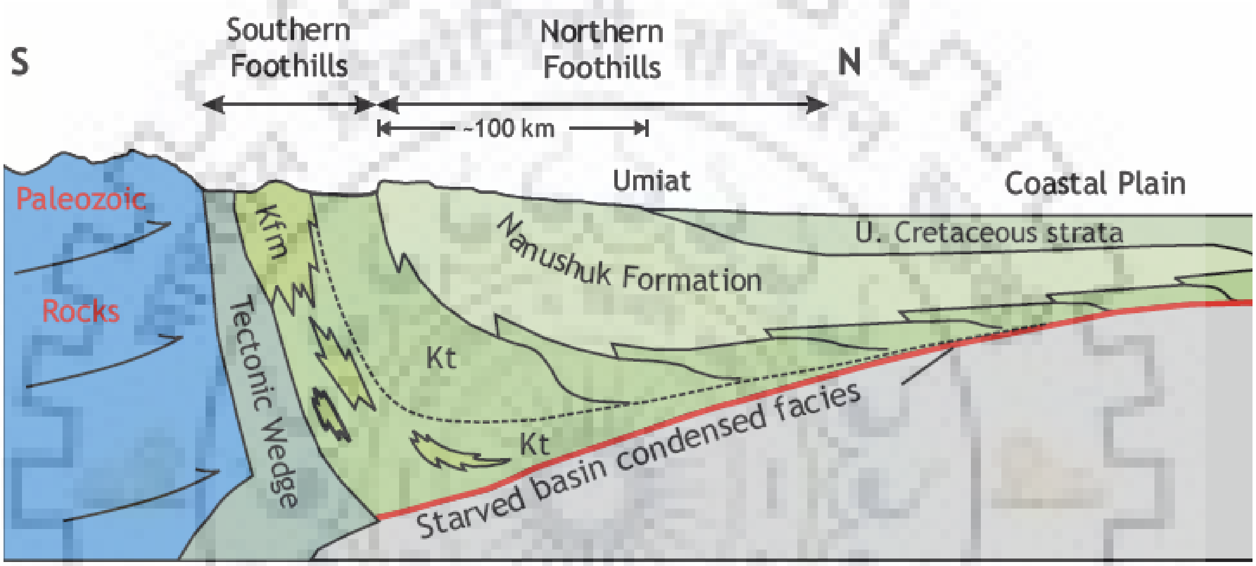


Figure-2.4- Detailed schematic cross section of Umiat Basin (after Lepain and others, 2009)

Petroleum systems modeling of the central fold-and-thrust belt suggests a main phase of mid-Cretaceous oil generation followed by additional Late Cretaceous burial and Paleocene structural trap formation, rendering a generally gas-prone region (Bird and Houseknecht, 2011). Many of the traps where the petroleum is confined are anticlines of large scales (in kilometers), locally modified by thrust faults that are likely to have formed at approximately 60 Ma (for example, O'Sullivan and others, 1997; Moore and others, 2004). Of these traps, in Umiat basin, petroleum is accumulated in along doubly plunging, gently folded anticline. Accumulations are in the Nanushuk Formation (Figure-2.3) and younger Cretaceous stratigraphy that is folded over structurally thickened Torok Formation. Both the Umiat and East Umiat fields are modified by thrust faults (Brosgé and Whittington, 1966; Molenaar, 1982; Kumar and others, 2002).

2.2 Tectonic Settings

The region has undergone a complex tectonic history, including several distinct orogenic events and significant anticlockwise rotation relative to the North American craton (Embry, 1990). The region is underlain by the North Slope sub-terrane of the Arctic Alaska-Chukotka micro plate (Moore, 1994). Until the opening of Canadian Basin in Jurassic, this microplate, also termed as the "proto Arctic Alaska microplate", did not evolve into a composite block of Alaskan sub-terranes (Macdonald et al., 2009).There are six discrete tectonic events that led to the present day configuration of the thrust belt in this area:

1. Emplacement of ophiolitic allochthonous over the distal continental margin rocks in Early Cretaceous time
2. Early Cretaceous uplift of the Barrow Arch rift margin, affecting the northern part of the Colville Basin
3. Contraction involving emplacement of distal continental margin and ophiolitic allochthonous onto the Endicott Mountains allochthonous and creation of a southward dipping flexural basin on the North Slope autochthonous
4. Mid-Cretaceous exhumation of imbricated rocks in the Brooks Range during northward propagation of the thrust front into the foreland
5. Minor thrusting in Late Cretaceous-Paleocene in the northern foreland to the northern limit of contractional structures
6. Regional exhumation of the orogeny and the foreland in Paleocene-Eocene time.

2.3 Basement Geology

Informally known as Basement complex, it is referred to all rocks beneath North Slope, Alaska which are older than Late Devonian-Mississippian Endicott Group (Bird, 1988). The basement complex is variably deformed, weakly metamorphosed to unmetamorphosed, and is composed of a variety of lithologies. The Barrow Arch, surrounding the Umiat basin in the North, represents the currently high-standing part of the rift shoulder that was formed during opening of the Amerasia basin. The other arches and platforms are believed to be tectonized early Paleozoic sediments that were intruded by Middle Devonian granites (Saltus, 2002).

Wells offshore and onshore northern NPRA confirm the basement is largely composed of fine grained, steeply inclined argillite, slate phyllite, or minor quartzites termed tectonized siliciclastics (Sherwood et al., 2002).The basement was divided into six groups based on composition and age: varicolored argillites, organic-rich siliceous argillite and chert, gray argillite with interbedded siltstone to sandstone, chert dominated conglomerate and sandstone. (Dumoulin, 2001)

The top of the basement deepens to south from structurally high Barrow arch (Bird, 1988). This trend is intervened by large basinal features including the Ikpikpuk-Umiat basin complex and the Meade basin. From these basins southward, basement is cut by numerous normal faults, faults which are present in these basins itself, that in places form complex horst and graben features. The age of basement-involved normal faulting is interpreted to be as young as Late Devonian and /or Early Mississippian because some of the normal faults fade up-section in the lower Lisburne Group (Saltus, 2002).

Chapter-3: Details about Data

Seismic data for this study was taken from National Petroleum Reserve-Alaska Data Archive, U.S Geological Survey which freely provides data for academic and research purposes. Five 2-D Seismic profiles were chosen for the purpose of processing from the U.S. Geological Survey's website (https://certmapper.cr.usgs.gov/data/apps/npra/). Along with the pre-processed data, observer's logs and survey notes were also provided on the website which helped with geometry and static correction in data processing. The five 2D seismic lines are given as (Figure 3.1):

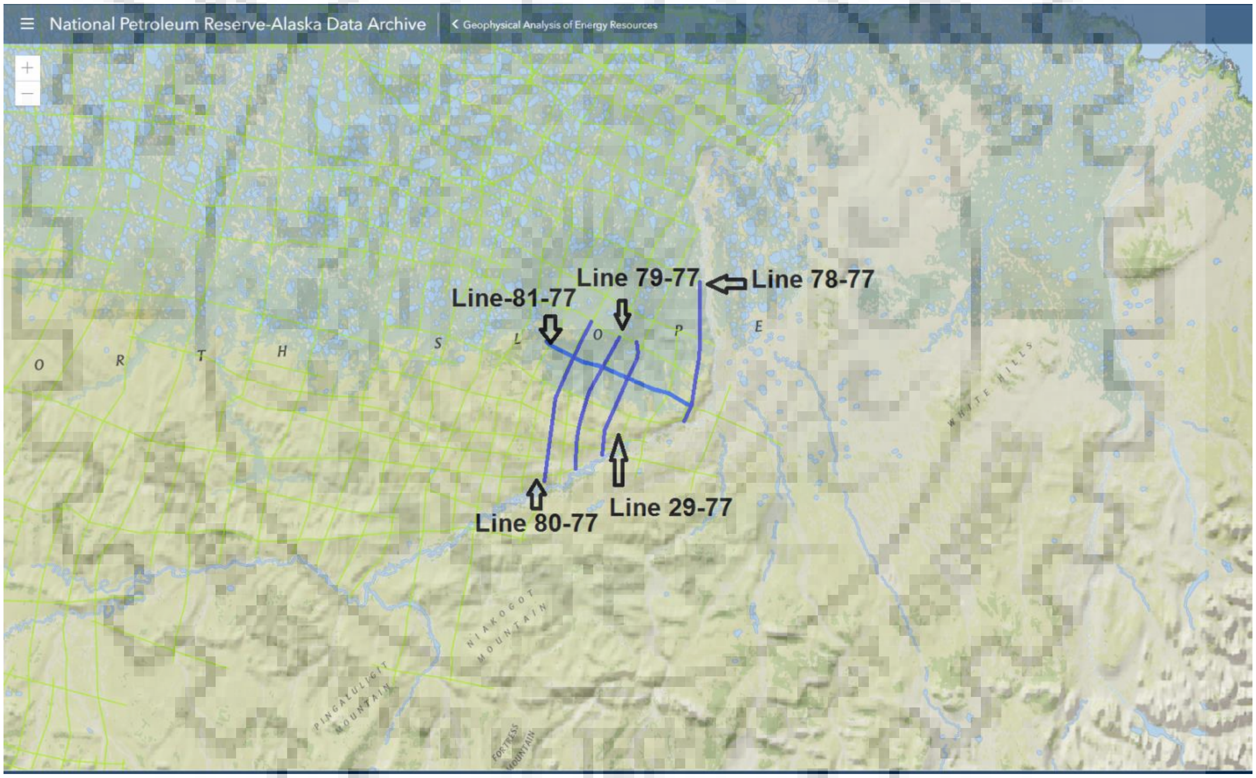


Figure-3.1- shows all the five profiles on a topographic map (after https://certmapper.cr.usgs.gov/data/apps/npra/)

Seismic Data Acquisition parameters of 2-D seismic line-

- Spread type: Split Spread
- Number of shots: 84
- Near offset: 110 ft
- Shot interval: 1760 ft

- Receiver interval : 220 ft
- Sampling interval: 2 ms
- Data length: 8 sec
- Number of active channels: 96
- Channel number close to shot : 48
- Nominal foldage: 6

Paradigm Software Suite was used in the processing these seismic line.

Chapter-4: Methodology

In this chapter, we will discuss the steps involved in processing and interpretation of the seismic data. Of all the processes done during seismic data processing, three processes are most important namely- Deconvolution, Stacking and Migration. All the other processes are used to enhance the effect of these primary processes. Velocity Analysis is another unique process of estimation of velocity to correct reflection travel times for non-zero offset section and to use this estimated velocity to compress the data into stacked section. Velocity analysis is done with the help of the semblance spectra. Semblance spectra is a 2D plot of semblance values with stacking/RMS velocity and time on x and y axis respectively. Semblance is a measure of coherence and it can be calculated by (Yilmaz, 2001):

$$\text{Semblance} = \frac{energy\ of\ the\ stacked\ traces}{mean\ energy\ of\ the\ component\ traces} \quad (4.1)$$

Basic theoretical workflow of processing of seismic data is given in Figure-4.1 below-

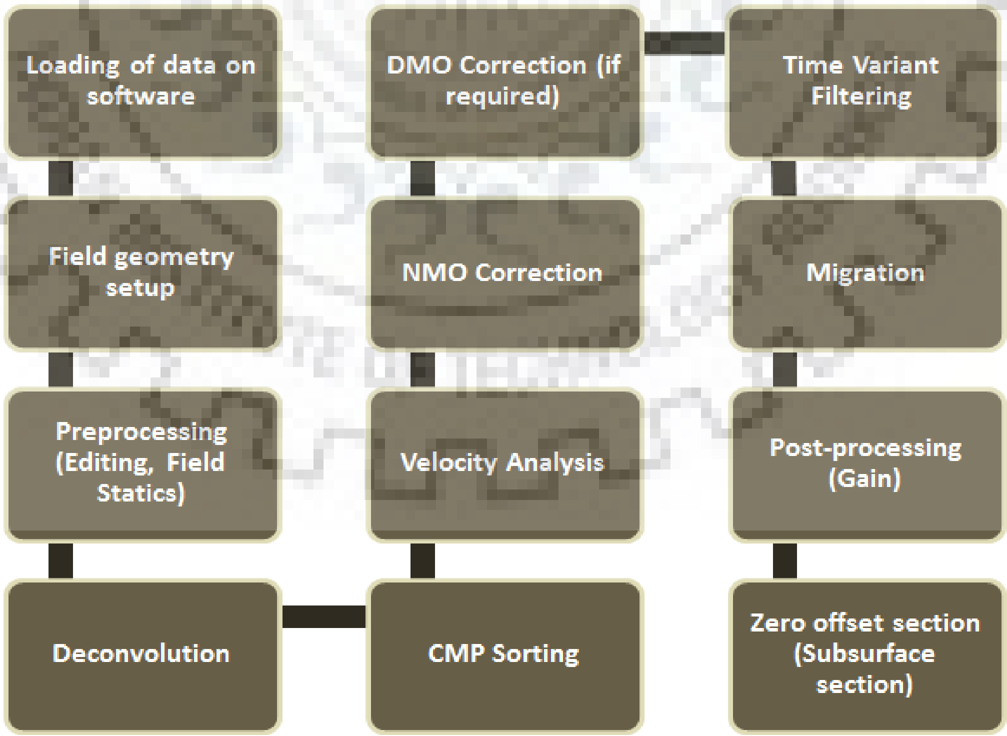


Figure-4.1- Processing of seismic data workflow (altered from Yilmaz, 2001)

Deconvolution is a process used to compress the basic wavelet in the recorded seismogram. We assume that when seismic wavelet is emitted and reflected back, due to changes in the velocity or density, with depth of the rock packages in the subsurface, the shape of the wavelet remains constant along the propagation path and the reflected signal will be the superposition of delayed wavelets. Each of these wavelets will be scaled according to reflectivity of the layers in subsurface (Figure 4.2). The goal of a deconvolution scheme is to remove the effect of the wavelet from the seismic trace and then correct for wave front divergence, thus retrieving the earth's reflectivity function Moreover, Deconvolution is also used to attenuate reverberations and short-period multiples. (Yilmaz, 2001; Arya, 1978)

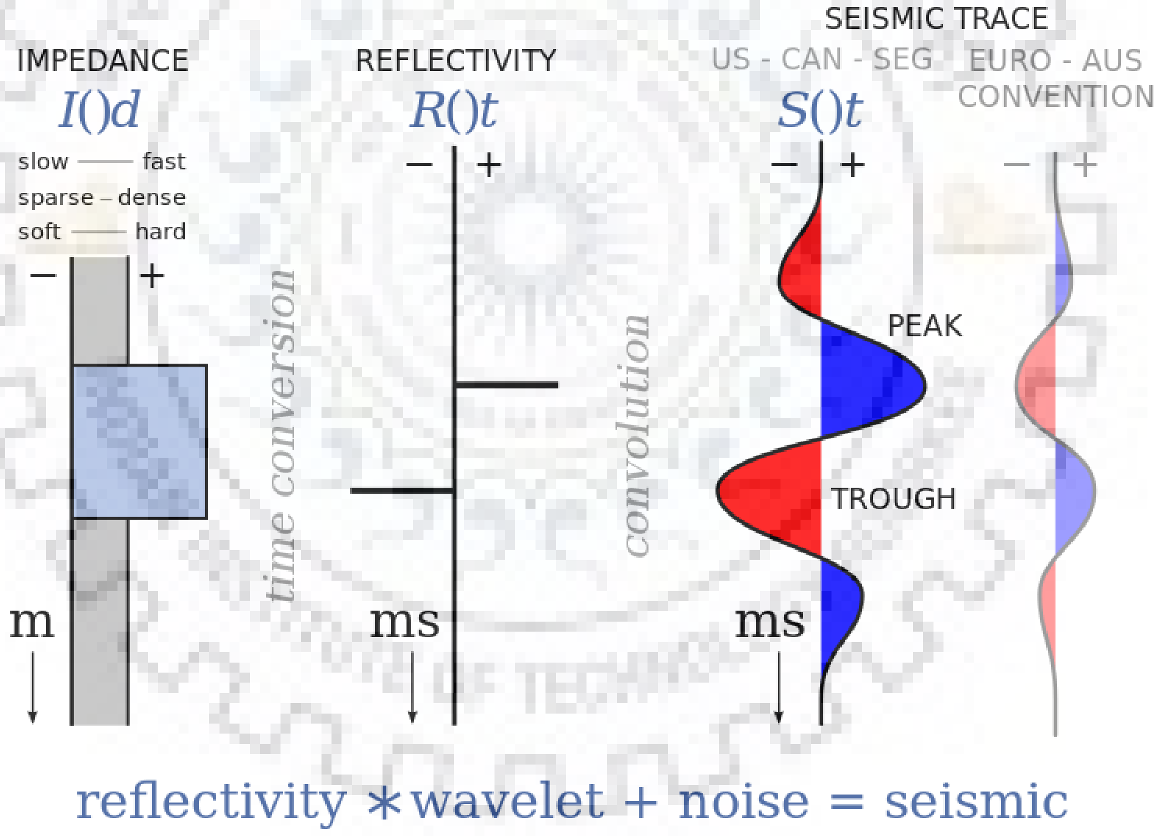


Figure-4.2- Schematic representation of Convolutional model (https://bit.ly/2V5YsKm)

There are two assumptions that are considered for deconvolution-

1. The earth is made up of horizontal layers of constant velocity
2. Compressional waves that propagates through layers, intersect these at normal incidences
3. The source waveform is stationary and remains constant when it travels through the subsurface.

While carrying out deconvolution, these assumptions are very important because variation in lateral velocity can change the output and consequently affect the reflection coefficients of the layer interface. The reflection coefficients vary with depth and collectively are known as reflectivity series (can be seen in Figure-4.2). Reflectivity series is composed of primary reflections.

Mathematical formulation of deconvolution is shown below (Yilmaz, 2001):

$$e(t) = f(t) * x(t) \qquad (4.2)$$

where $f(t)$ is a filter operator defined such that convolution of $f(t)$ with the known seismogram $x(t)$ yields an estimate of the earth's impulse response $e(t)$.

$$x(t) = w(t) * e(t) \qquad (4.3)$$

where $x(t)$, input seismogram is a result of convolution of input seismic wavelet, $w(t)$, and the earth's impulse response $e(t)$. By substituting equation 4.2 into equation 4.3, we will get:

$$x(t) = w(t) * f(t) * x(t) \qquad (4.4)$$

When $x(t)$ is eliminated from both sides of the equation, the following expression results:

$$\delta(t) = w(t) * f(t) \qquad (4.5)$$

where $\delta(t)$ represents the Kronecker delta function. By solving equation (4.5) for the filter operator $f(t)$ we obtain:

$$f(t) = \delta(t) * (1/w(t)) \quad (4.6)$$

Therefore, the filter operator $f(t)$ is the mathematical inverse of the input seismic wavelet $w(t)$.

In seismic data processing, seismic input wavelet is unknown and as a result, statistical deconvolution is used where seismic input wavelet is estimated statistically from the input seismogram. If it is known then deterministic type of deconvolution is used.

Deconvolved gathers are further sorted from Common shot point domain to Common depth point domain. Deconvolution tries to flatten the amplitude spectrum, but it can never achieve it therefore spectral balancing in CDP domain is done. Spectral balanced gathers are then used for further velocity analysis. At this step, velocity analysis is done at coarser CDP intervals. (Sheriff, 1995)

From velocity analysis, velocity spectra for each CDP are generated. Stacking velocities are selected on the basis of maximum flatness to the primary events at finite intervals; linearly interpolating velocities between the interval Picked velocities are smoothed before applying NMO correction to the data. On applying NMO, events at shallow and large offsets suffer NMO stretch, which is a frequency distortion due to which events are shifted to lower frequencies. Because of NMO stretch, stacking of the NMO-corrected CMP gather will severely damage the shallow events. To remove the effect of NMO stretch, a mute function is applied (Yilmaz, 2001).

Next step followed by NMO correction is stacking wherein the amplitude of all traces at a particular point of time are summed together and then dividing by the number of component traces, averaging the amplitude of traces as a result. This results into increase of the Signal-to-Noise (SNR) ratio. Brute stack gives an idea about the subsurface structure, can be used for selecting the pilot trace, and calculates the residual statics in the different events. After generating the brute stack, residual statics is calculated to make the events more coherent (Yilmaz, 2001).

The move out in CMP gathers does not always conform to a perfect hyperbolic trajectory. This often is because of near-surface velocity irregularities that cause a static or dynamic distortion problem. Negative move-outs are caused due to lateral velocity variations caused by a complex overburden. Thus, residual statics is performed to improve stacking quality; this is done in a surface-consistent manner where time shifts are dependent only on shot and receiver locations, not on the ray paths from shots to receivers (Yilmaz, 2001).

After correcting the CDP traces for residual statics, migration is carried out. Migration is a process of moving the reflections to its true location. All of the many methods of doing migration are focused on solutions to the scalar wave equation; these are the solutions to a partial differential equation which shows how the wave may travel through the surface of Earth.

$$\frac{\partial^2 P}{\partial z^2} + \frac{\partial^2 P}{\partial x^2} = \frac{1}{V^2}\frac{\partial^2 P}{\partial t^2} \quad (4.7)$$

where P(x, z, t) is the seismic amplitude as a function of reflection time t at any position (x, z) in the subsurface, and V (x,z) is the seismic wave velocity in the subsurface. Seismic energy sources create energy disturbances which are presumed to follow the solution of wave equation. Migration, then, involves a running of the wave equation backward in time, starting with the measured waves at the earth's surface P(x, z = 0, t), in effect pushing the waves backward and downward to their reflecting locations. (Lamer, 1992)

Depending on the subsurface conditioned, different migration strategies are employed to get desirable results which are easy to interpret two primary types of migration that are applied are-

- Time Migration- This migration is used for seismic data in time coordinates. This type of migration assumes that only mild lateral velocity variations is present and helps in locating complex subsurface structures, particularly salt. Some popularly used time migration algorithms are: Stolt migration, Gazdag and Finite-difference migration (Yilmaz, 2001).

- Depth migration- This migration takes in account lateral velocity variation by incorporating the seismic velocity model as this type of migration is carried out in depth coordinates which are calculated from time coordinate. Disadvantage of this process is it is resource intensive and iterative. Some of the popularly used depth migration algorithms are Kirchhoff depth migration, Reverse Time Migration (RTM), Gaussian Beam Migration and Wave-equation migration (Yilmaz, 2001).

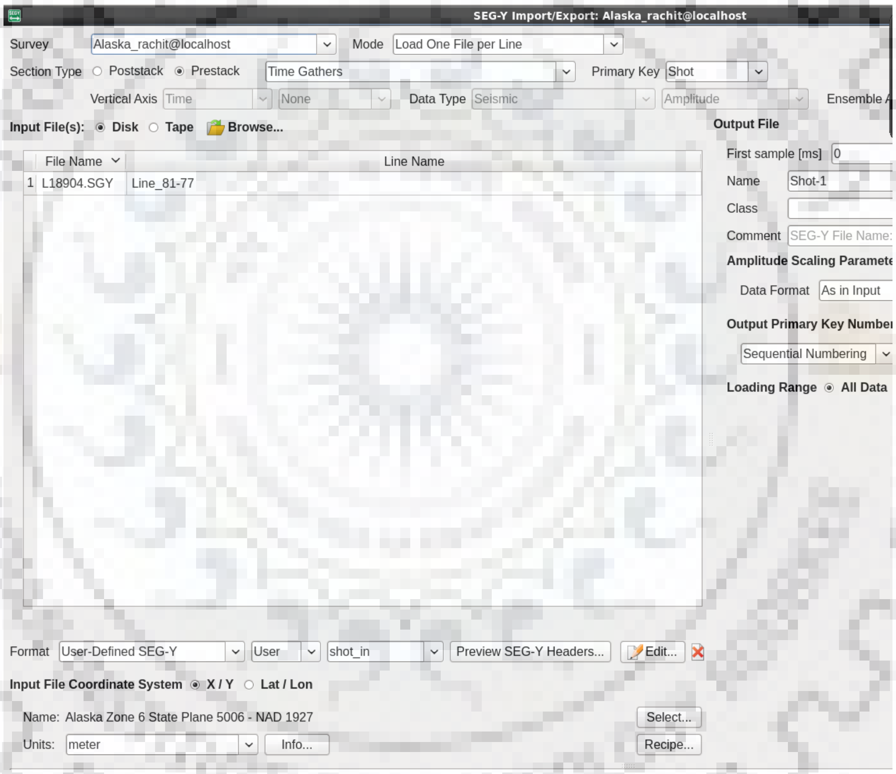
Prominently two modules of Paradigm were used in processing of the seismic data:

- Pre-processing, multiple attenuation and deconvolution was done using ECHOS® by Paradigm. ECHOS® provides a comprehensive library of seismic processing applications for geometry definition, near surface static corrections, deconvolution, wavelet shaping, demultiple, deghosting, trace regularization and interpolation, migration, noise suppression and signal enhancement; enabling the adaptive construction of data dependent processing workflows to solve modern geophysical challenges.
- The time domain and depth domain processing including the velocity analysis, Pre-Stack Time Migration, velocity modelling was done using GEODEPTH® by Paradigm. GEODEPTH® performs seismic imaging in depth. It also integrates seismic interpretation, velocity analysis & model building, time-to-depth conversion, depth imaging, earth modelling. GEODEPTH® enables us to obtain a verified depth velocity model of the subsurface together with a consistent depth image and depth migrated gathers for our marine and land surveys. The key data sources for GEODEPTH® are prestack gathers. We can also load time and time migrated stacks, velocity sections, velocity functions and interpretation picks.

4.1 Processing using Paradigm

4.1.1 Loading and Merging of Data

The first process carried out is loading of the data into Paradigm using line 81-77 profile. The software specifically demands that the data should be available in seg-y (.SGY) format. In Paradigm, Files menu contains an option “SEG-Y Import and Create survey” (using Fig-4.3) where data, both prestack and post-stack, can be loaded.


SEG-Y Import/Export: Alaska_rachit@localhost

Survey: Alaska_rachit@localhost
Mode: Load One File per Line
Section Type: ○ Poststack ● Prestack
Time Gathers
Primary Key: Shot
Vertical Axis: Time
None
Data Type: Seismic
Amplitude
Input File(s): ● Disk ○ Tape

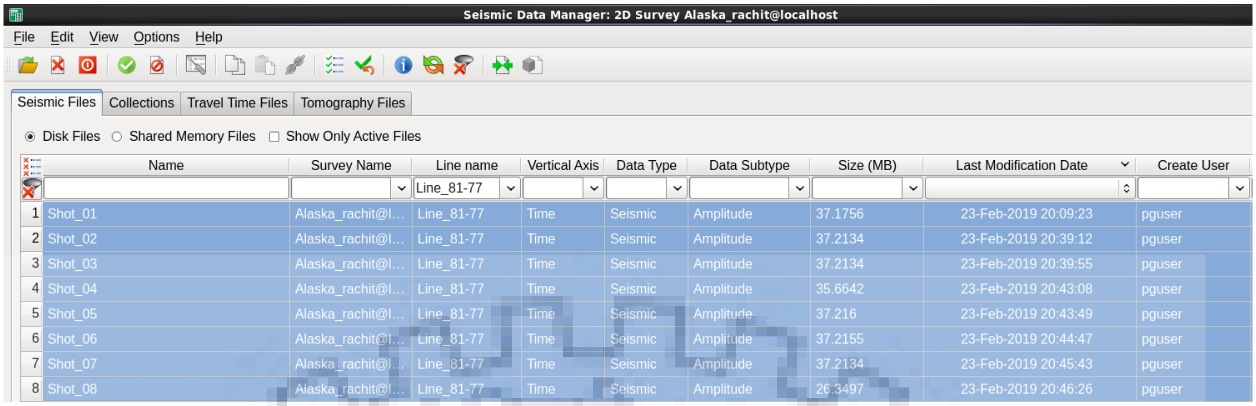
	File Name	Line Name
1	L18904.SGY	Line_81-77

Output File
First sample [ms]: 0
Name: Shot-1
Class:
Comment: SEG-Y File Name:
Amplitude Scaling Paramete
Data Format: As in Input
Output Primary Key Numbei
Sequential Numbering
Loading Range ● All Data

Format: User-Defined SEG-Y
User
shot_in
Input File Coordinate System ● X / Y ○ Lat / Lon
Name: Alaska Zone 6 State Plane 5006 - NAD 1927
Units: meter

Figure-4.3- Window used for loading the data

As the given data was segmented, each segment was loaded independently in the survey initially as shot gather. Using Seismic Data Manager in ECHOS menu on the main screen of Paradigm, all the segments are merged.



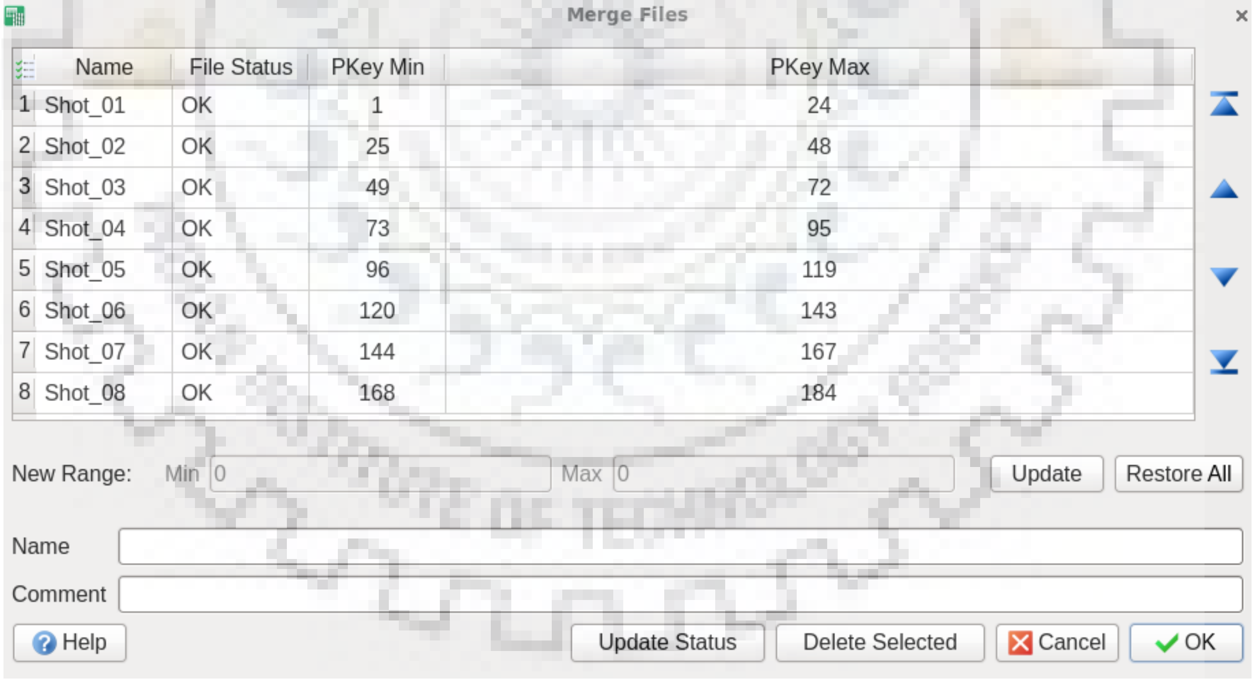
● Disk Files ○ Shared Memory Files ☐ Show Only Active Files

Line name: Line_81-77

	Name	Survey Name	Line name	Vertical Axis	Data Type	Data Subtype	Size (MB)	Last Modification Date	Create User
1	Shot_01	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	37.1756	23-Feb-2019 20:09:23	pguser
2	Shot_02	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	37.2134	23-Feb-2019 20:39:12	pguser
3	Shot_03	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	37.2134	23-Feb-2019 20:39:55	pguser
4	Shot_04	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	35.6642	23-Feb-2019 20:43:08	pguser
5	Shot_05	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	37.216	23-Feb-2019 20:43:49	pguser
6	Shot_06	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	37.2155	23-Feb-2019 20:44:47	pguser
7	Shot_07	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	37.2134	23-Feb-2019 20:45:43	pguser
8	Shot_08	Alaska_rachit@l...	Line_81-77	Time	Seismic	Amplitude	26.3497	23-Feb-2019 20:46:26	pguser

Figure-4.4- Seismic Data Manager

But before merging them, HDRMATH module of ECHOS is used to change the numbering of the shots of each of the segment as a continuous single shot gather. Fig.-4.4 shows different segments of shots being selected in order to combine them using merge in Options in menu.



	Name	File Status	PKey Min	PKey Max
1	Shot_01	OK	1	24
2	Shot_02	OK	25	48
3	Shot_03	OK	49	72
4	Shot_04	OK	73	95
5	Shot_05	OK	96	119
6	Shot_06	OK	120	143
7	Shot_07	OK	144	167
8	Shot_08	OK	168	184

New Range: Min 0 Max 0

Name

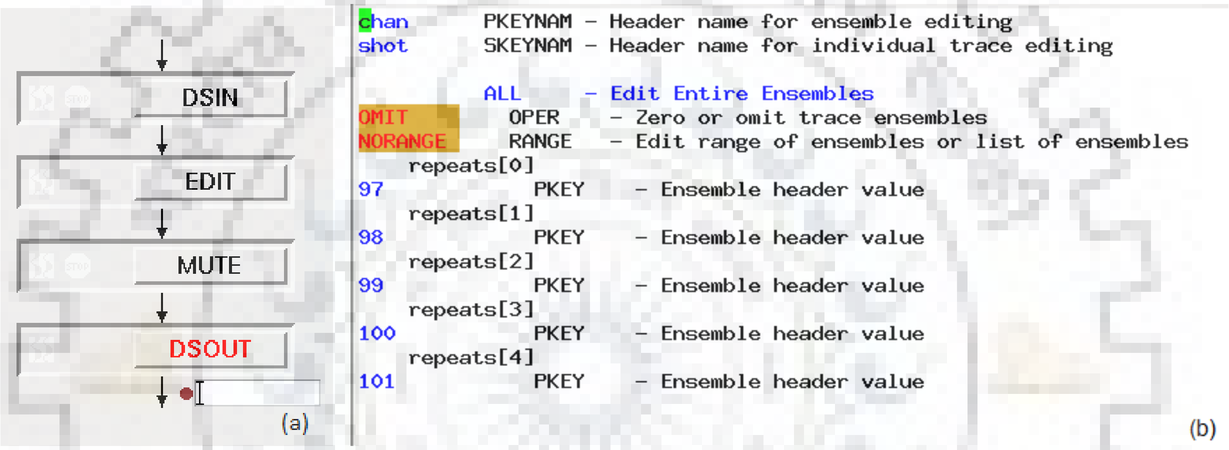
Comment

Figure- 4.5- Merge files window

Fig-4.5 shows merge file window where all the segments properly numbered are arranged. In the window, “Name” is used to create and name the new merged file, that is shot gather (in this case Line 81-77), by selecting all the segments. Similar steps have done for all the profiles.

4.1.2 Editing

After merging the segments and creating shot gather, editing is the next process to be carried out (Figure 4.6). In editing, the redundant traces from the shot gather are removed completely. In most of the cases, these are the traces recorded in the auxiliary channel. These contain noise which must be removed for smooth processing.



```
chan        PKEYNAM - Header name for ensemble editing
shot        SKEYNAM - Header name for individual trace editing

            ALL      - Edit Entire Ensembles
OMIT          OPER    - Zero or omit trace ensembles
NORANGE       RANGE   - Edit range of ensembles or list of ensembles
    repeats[0]
97              PKEY    - Ensemble header value
    repeats[1]
98              PKEY    - Ensemble header value
    repeats[2]
99              PKEY    - Ensemble header value
    repeats[3]
100             PKEY    - Ensemble header value
    repeats[4]
101             PKEY    - Ensemble header value
```

Figure-4.6 (a) Processing flow for editing using EDIT Module. (b) OMIT operator is used to remove channel number 97, 98, 99,100 and 101

DSIN and DSOUT modules are no processing modules. These modules start and end the processing flow by allowing the user to give an input to the program through DSIN and obtain an output in DSOUT. Both these modules use LABEL option for naming input and output file. The same is true for all the processes that are included in this case.

EDIT module alters seismic traces in one of three ways:

- It reduces trace amplitude to zero (kills traces), and passes them on in the processing stream.
- It drops (omits) traces from processing.
- It reverses trace amplitude polarity

PKEYNAM is the primary key name for which the EDIT module changes that property of the ensemble and *chan* is used as PKEYNAM to remove traces corresponding to channel number 97, 98, 99,100 and 101 for all the shot points SKEYNAM is used for individual trace editing and as each shot point needs to be altered thus, *shot* is the input for SKEYNAM.

There are two options with which to obtain the three types of editing performed by EDIT. They are ALL and SEL. The options differ only in the way data is selected for editing.

- ALL - Polarity reversal, omitting or zeroing is applied to all traces within specified ensembles. With the ALL option, the user supplies PKEY values identifying ensembles for editing. Parameter RANGE determines whether the supplied PKEY values are treated as individual ensembles or as pairs of ensembles, with each pair designating a range to be edited.
- SEL - Polarity reversal, omitting or zeroing is applied to individual traces or to ranges of traces within an ensemble or a range of ensembles. With the SEL option, the user selects ranges of ensembles for editing, using parameters PKEYFR and PKEYTO. Traces within the ensembles are designated with parameter SKEY, which can be repeated to identify any number of traces. Parameter RANGE determines whether the supplied SKEY values are treated as individual traces or as pairs of traces, with each pair designating a range to be edited.

Both EDIT options, ALL and SEL, may be used in a single call to the program.

The type of editing that EDIT performs is determined by two factors: the value for parameter OPER and whether the PKEY values are supplied as positive or negative numbers. The values for parameter OPER may be KILL or OMIT. KILL zeros trace amplitude in the designated ensembles. OMIT drops ensembles of traces from processing. OMIT is the default value. To reverse trace amplitude polarity, the PKEYs must be supplied as negative values, and must also supply KILL or OMIT as the value for OPER. Polarity reversal overrides KILL and OMIT.

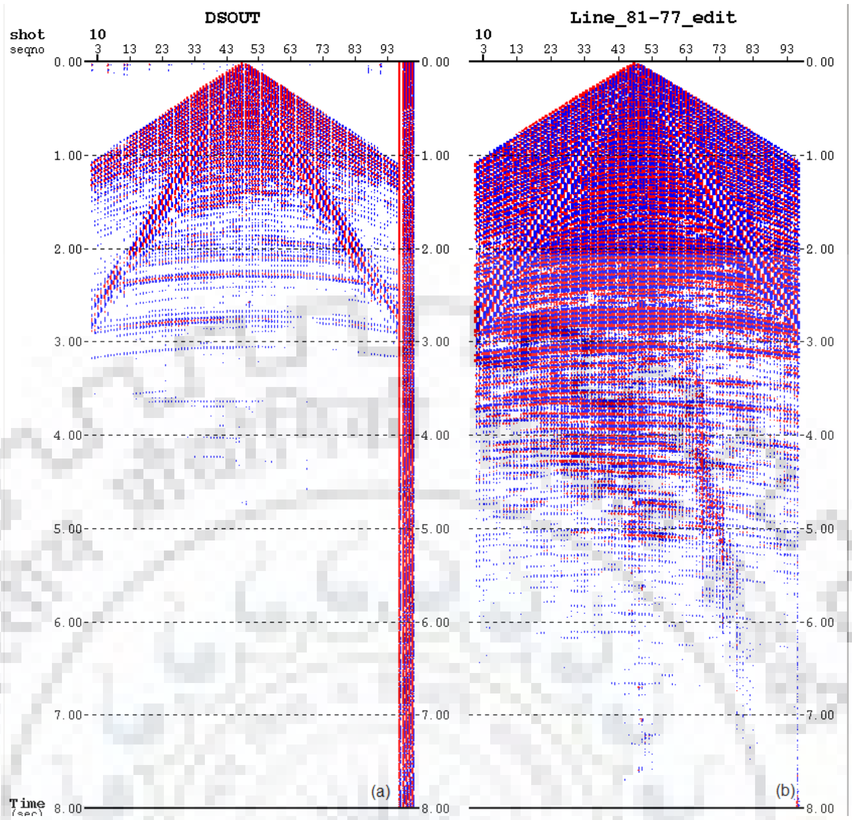


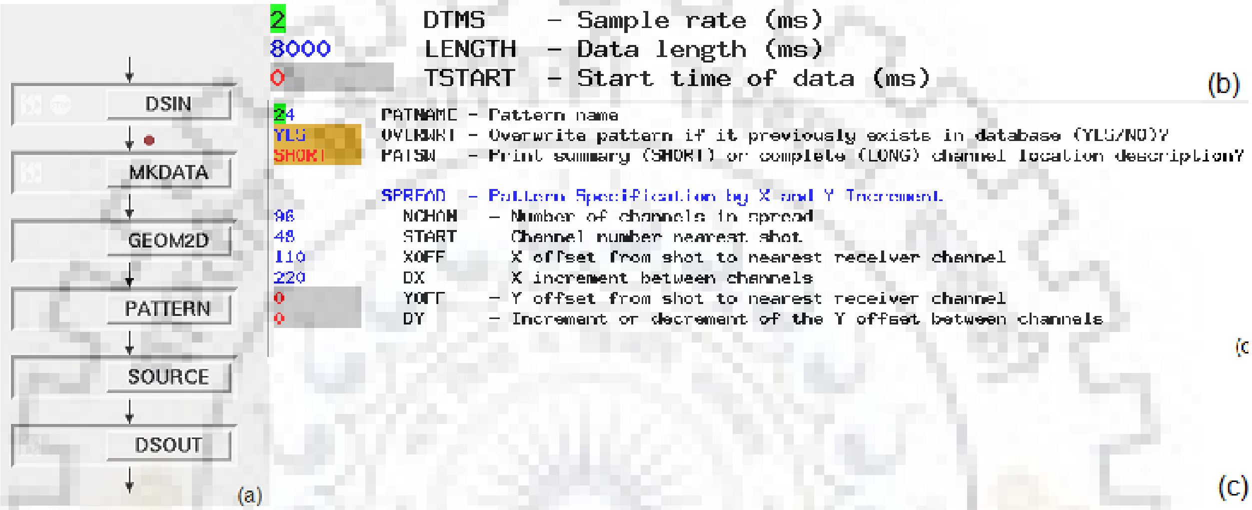
Figure- 4.7- (a) Input raw shot gather (b) After applying EDIT module

OMIT is used to drop the useless channels containing redundant data in channel number 97, 98, 99, 100 and 101. The output clearly shows the difference from the initial shot gather obtained from merging. The process not only cleans the data but also enhances events which were earlier not visible as can be seen in Figure-4.7.

As can be seen in Fig-4.7, shot point numbered 10 was used as a sample to show the results and analyze the differences caused by using the modules. The same shot point is consistently used throughout the case as sample shot point. Processing steps are applied to all the shot points of five lines.

4.1.3 Geometry Merge

Geometry merge is done in order to create geometry headers for seismic data traces. It accesses the coordinate information and assign traces header values by taking input of geometry parameters (Figure 4.8a).



```
2          DTMS     - Sample rate (ms)
8000       LENGTH   - Data length (ms)
0          TSTART   - Start time of data (ms)

24         PATNAME - Pattern name
YES        OVERWRT - Overwrite pattern if it previously exists in database (YES/NO)?
SHORT      PRTSW   - Print summary (SHORT) or complete (LONG) channel location description?

           SPREAD  - Pattern Specification by X and Y Increment.
96           NCHAN   - Number of channels in spread
48           START     Channel number nearest shot
110          XOFF      X offset from shot to nearest receiver channel
220          DX        X increment between channels
0            YOFF    - Y offset from shot to nearest receiver channel
0            DY      - Increment or decrement of the Y offset between channels
```

Figure- 4.8 (a) Processing flow for Geometry Merge (b) Parameters used in MKDATA module (c) Parameters used in PATTERN module to describe pattern used for acquisition

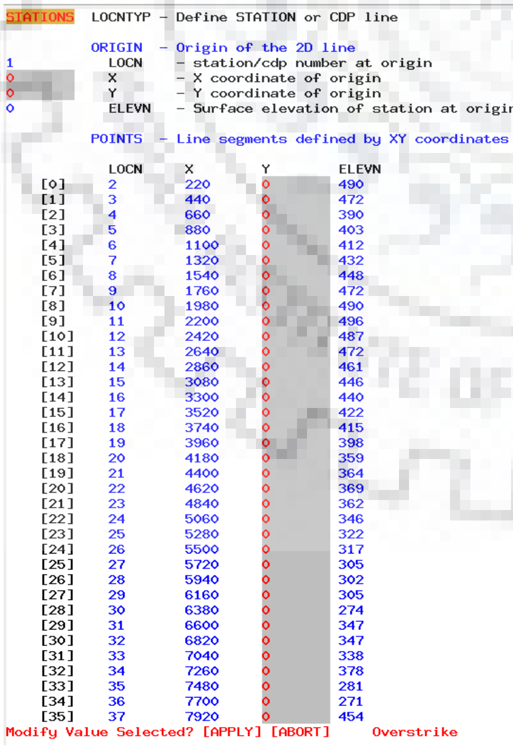
MKDATA, in Fig-4.8 (b), is an input program. It is distinguished from other input programs by the fact that it creates the input dataset according to user specification. MKDATA is used to create zero (dummy) traces for testing. For each trace created by MKDATA, a trace header is also created. The following trace headers are always created when MKDATA is run:

- seqno - Trace sequence number within the ensemble.
- lasttr - A flag that indicates whether or not the trace is the last trace in the ensemble.
- type - A flag that indicates the type of trace - data trace or auxiliary trace. All traces created by MKDATA are flagged as data traces.

The three programs are GEOM2D, PATTERN, and SOURCE, executed in that order as can be seen in Fig-4.8(a). These programs perform calculations based on user-supplied parameters to establish the geographical locations of the shots, the geophones, and the common depth points (CDPs). They do not process seismic data. According to the observer's log, information was fed into all of these modules to create geometry.

PATTERN, in Fig-4.8 (c), eliminates the need to define a separate receiver configuration for each shot on the line. Using parameters supplied by the user, PATTERN creates a shot-receiver pattern that is subsequently superposed by program SOURCE on appropriate station locations on the established line. In addition, once a pattern has been defined and stored in the seismic database, it may be used for any or all lines belonging to a particular survey. PATTERN is also reentrant; therefore, it can be run multiple times in the same job to define multiple patterns.

There are three patterns available in PATTERN. They are PXY, PSTAT, and SPREAD. PXY and SPREAD are primarily intended to define patterns associated with marine acquisition. Both are distance relative, locating receivers by x and y offsets from the shot point. The SPREAD option is a more concise method for defining a pattern than PXY, provided that the receiver interval remains constant.



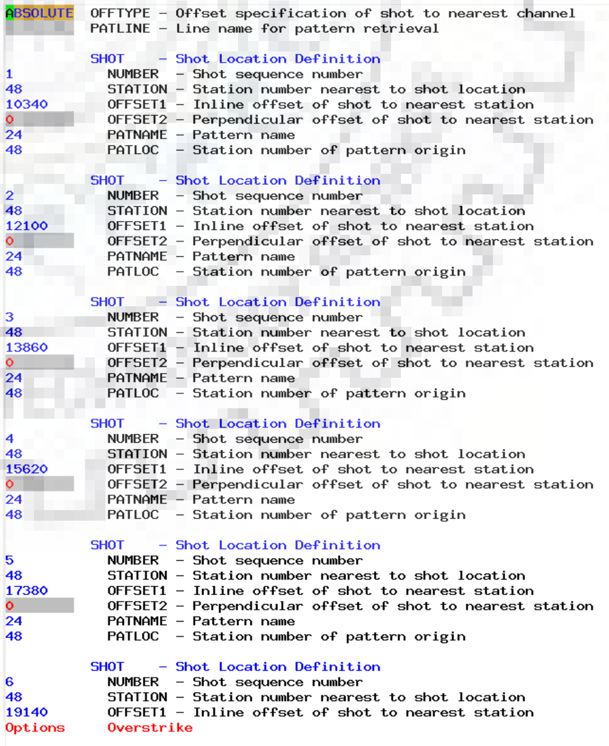
```
STATIONS  LOCNTYP - Define STATION or CDP line

          ORIGIN  - Origin of the 2D line
1           LOCN    - station/cdp number at origin
0           X       - X coordinate of origin
0           Y       - Y coordinate of origin
0           ELEVN   - Surface elevation of station at origin

          POINTS  - Line segments defined by XY coordinates

            LOCN      X         Y         ELEVN
      [0]   2         220       0         490
      [1]   3         440       0         472
      [2]   4         660       0         390
      [3]   5         880       0         403
      [4]   6         1100      0         412
      [5]   7         1320      0         432
      [6]   8         1540      0         448
      [7]   9         1760      0         472
      [8]   10        1980      0         490
      [9]   11        2200      0         496
      [10]  12        2420      0         487
      [11]  13        2640      0         472
      [12]  14        2860      0         461
      [13]  15        3080      0         446
      [14]  16        3300      0         440
      [15]  17        3520      0         422
      [16]  18        3740      0         415
      [17]  19        3960      0         398
      [18]  20        4180      0         359
      [19]  21        4400      0         364
      [20]  22        4620      0         369
      [21]  23        4840      0         362
      [22]  24        5060      0         346
      [23]  25        5280      0         322
      [24]  26        5500      0         317
      [25]  27        5720      0         305
      [26]  28        5940      0         302
      [27]  29        6160      0         305
      [28]  30        6380      0         274
      [29]  31        6600      0         347
      [30]  32        6820      0         347
      [31]  33        7040      0         338
      [32]  34        7260      0         378
      [33]  35        7480      0         281
      [34]  36        7700      0         271
      [35]  37        7920      0         454
Modify Value Selected? [APPLY] [ABORT]     Overstrike
```

(a)



```
ABSOLUTE  OFFTYPE - Offset specification of shot to nearest channel
          PATLINE - Line name for pattern retrieval

          SHOT     - Shot Location Definition
1           NUMBER  - Shot sequence number
48          STATION - Station number nearest to shot location
10340       OFFSET1 - Inline offset of shot to nearest station
0           OFFSET2 - Perpendicular offset of shot to nearest station
24          PATNAME - Pattern name
48          PATLOC  - Station number of pattern origin

          SHOT     - Shot Location Definition
2           NUMBER  - Shot sequence number
48          STATION - Station number nearest to shot location
12100       OFFSET1 - Inline offset of shot to nearest station
0           OFFSET2 - Perpendicular offset of shot to nearest station
24          PATNAME - Pattern name
48          PATLOC  - Station number of pattern origin

          SHOT     - Shot Location Definition
3           NUMBER  - Shot sequence number
48          STATION - Station number nearest to shot location
13860       OFFSET1 - Inline offset of shot to nearest station
0           OFFSET2 - Perpendicular offset of shot to nearest station
24          PATNAME - Pattern name
48          PATLOC  - Station number of pattern origin

          SHOT     - Shot Location Definition
4           NUMBER  - Shot sequence number
48          STATION - Station number nearest to shot location
15620       OFFSET1 - Inline offset of shot to nearest station
0           OFFSET2 - Perpendicular offset of shot to nearest station
24          PATNAME - Pattern name
48          PATLOC  - Station number of pattern origin

          SHOT     - Shot Location Definition
5           NUMBER  - Shot sequence number
48          STATION - Station number nearest to shot location
17380       OFFSET1 - Inline offset of shot to nearest station
0           OFFSET2 - Perpendicular offset of shot to nearest station
24          PATNAME - Pattern name
48          PATLOC  - Station number of pattern origin

          SHOT     - Shot Location Definition
6           NUMBER  - Shot sequence number
48          STATION - Station number nearest to shot location
19140       OFFSET1 - Inline offset of shot to nearest station
Options     Overstrike
```

(b)

Figure-4.9 (a) Parameters used in GEOM2D module (b) Parameters used in SOURCE module

GEOM2D is the first of three programs, in Fig-4.9(a), that define the geometry for a seismic line. GEOM2D defines a series of reference locations, or stations, to which CDPs, shots, and receivers are assigned. Program GEOM2D defines a set of reference station locations upon which to locate shots and receivers. In GEOM2D module, station coordinates along with the statics were filled.

The information defined by the geometry programs is stored in the seismic database where it is accessed by other programs. Among the programs that access the geometry is GEOMLD, which is the program that writes the geometry values into the seismic trace headers.

All information stored in the seismic database is organized by the survey. Data is organized according to seismic line, and for any given line the information is stored in models and in binary files. Models are simply mechanisms for organizing the information. The models contain sets of numeric values that represent the various characteristics of the seismic data in the line.

The database models for a seismic line are created by running particular programs. Three models, STATION, SHOT, and CDP, are automatically created when GEOM2D, PATTERN, and SOURCE are run. GEOM2D creates the STATION and CDP models; SOURCE creates the SHOT model. It is in these models that the geometry values defined by running GEOM2D, PATTERN, and SOURCE are stored. STATION, SHOT, and CDP are the only models defined in the database for a seismic line.

The values stored in the database models are referred to in ECHOS as event attributes. A number of programs run after the geometry programs may define and store event attributes in the models for the line. These event attributes are accessed and used by other programs in the processing sequence.

After program SOURCE, in Fig-4.9 (b), establishes the position on the line of each shot, program GEOMLD determines the actual geographical coordinates of the receivers by adding to the shot location coordinates the relative x and y receiver offsets defined by PATTERN.

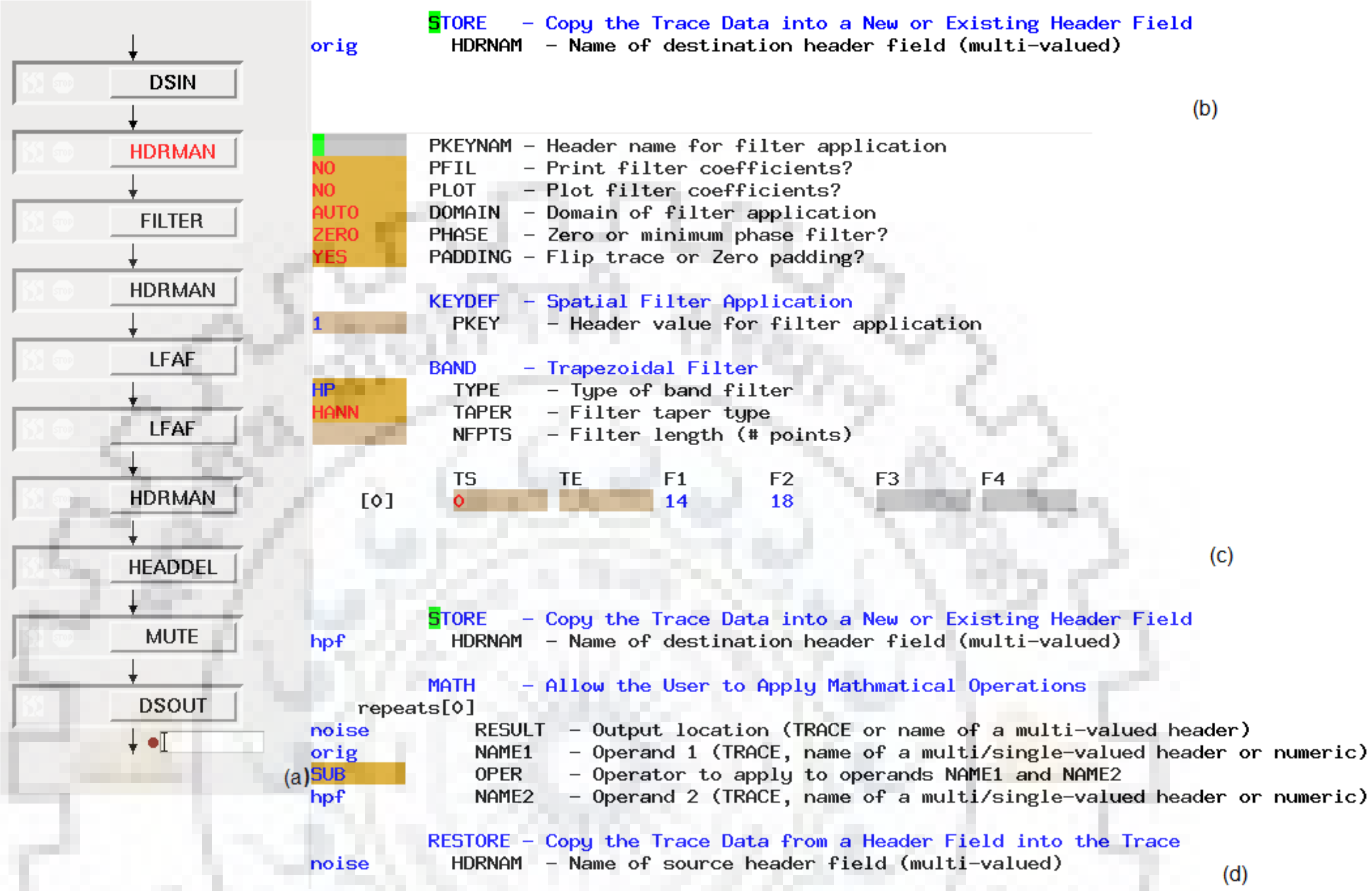
4.1.4 Ground roll Removal

Ground roll is coherent noise majorly found during land seismic surveys which are caused due to the channeling of Rayleigh waves within the low velocity surface layers. Vertical component of ground roll is composed of dispersive Rayleigh waves, whose different frequency components travel at different velocities, leading to long complex wave-trains that change as the length of the path traveled increases.

Ground roll are mostly characterized by low frequencies and high amplitudes and usually dominate near-source traces on seismic records. Ground roll can obscure signal and degrade overall data quality, but can be removed through careful selection of source and geophone arrays, filters and stacking parameters (Saatcilar, 1988; Deighan, 1997).

Paradigm has some modules which can be used to reduce the effect of ground roll on seismic data. There are many ways of removing ground roll from the data by attenuating the effect of ground roll include frequency filtering, FK filtering (Yilmaz, 2001), radon transform (Liu and Marfurt, 2004), wavelet transform (Deighan and Watts, 1997), and the curvelet transform. Yarham and Herrmann {2008) applied the S transform to ground-roll attenuation. But in this case, simple bandpass filters were used to remove ground roll.

To identify the frequency spectra correlated to ground roll, bandpass filtering is applied by using FILTER module (Figure 4.10a). Other than bandpass filtering, FILTER module can also be used for Notch filtering, Band filtering with tapering, Filtering using filter coefficients supplied by the user, Spectrum band-pass filtering and Butterworth band-pass filtering



```
             STORE    - Copy the Trace Data into a New or Existing Header Field
orig           HDRNAM  - Name of destination header field (multi-valued)

             PKEYNAM - Header name for filter application
NO           PFIL    - Print filter coefficients?
NO           PLOT    - Plot filter coefficients?
AUTO         DOMAIN  - Domain of filter application
ZERO         PHASE   - Zero or minimum phase filter?
YES          PADDING - Flip trace or Zero padding?

             KEYDEF  - Spatial Filter Application
1              PKEY    - Header value for filter application

             BAND    - Trapezoidal Filter
HP             TYPE    - Type of band filter
HANN           TAPER   - Filter taper type
               NFPTS   - Filter length (# points)

               TS        TE        F1        F2        F3        F4
    [0]        0                   14        18

             STORE    - Copy the Trace Data into a New or Existing Header Field
hpf            HDRNAM  - Name of destination header field (multi-valued)

             MATH     - Allow the User to Apply Mathmatical Operations
    repeats[0]
noise            RESULT  - Output location (TRACE or name of a multi-valued header)
orig             NAME1   - Operand 1 (TRACE, name of a multi/single-valued header or numeric)
SUB              OPER    - Operator to apply to operands NAME1 and NAME2
hpf              NAME2   - Operand 2 (TRACE, name of a multi/single-valued header or numeric)

             RESTORE - Copy the Trace Data from a Header Field into the Trace
noise          HDRNAM  - Name of source header field (multi-valued)
```

Figure-4.10 (a) Processing flow for Groundroll removal (b) Parameters used in HDRMAN-1 (c) Parameters used in FILTER (d) Parameters used in HDRMAN-2

HDRMAN, in Fig-4.10 (b) and 4.10 (d), facilitates the use of the trace header as a computational buffer for trace data. STORE and RESTORE operations are designed for copying the original or processed data between trace and multi-valued headers with the same length as trace data. RESULT specifies the output location of the process result. RESULT can be either a header name or trace.

In Fig-4.10 (b), ***orig*** header field is created which contains the “original” input data using HDRMAN module. Next, FILTER module is added which creates a bandpass filter containing frequencies 14 Hz to 18 Hz and above. FILTER module has a special characteristic that it can retrieve and apply filters designed and stored in the seismic database by other programs. This property of the module is used in order to filter out only that part of signal which corresponds to groundroll.

In Fig-4.10 (d), another header file is created named as ***hpf*** using the same module of HDRMAN again the second time (HDRMAN-2). It contains the same part of data corresponding to the signal extracted from FILTER module. Now, using MATH operator in the HDRMAN module, a resultant header file is created named ***noise****,* which is an output by subtracting ***hpf*** from ***orig.*** A part of ground roll is removed by simple bandpass filtering and the remaining part is removed using LFAF module.

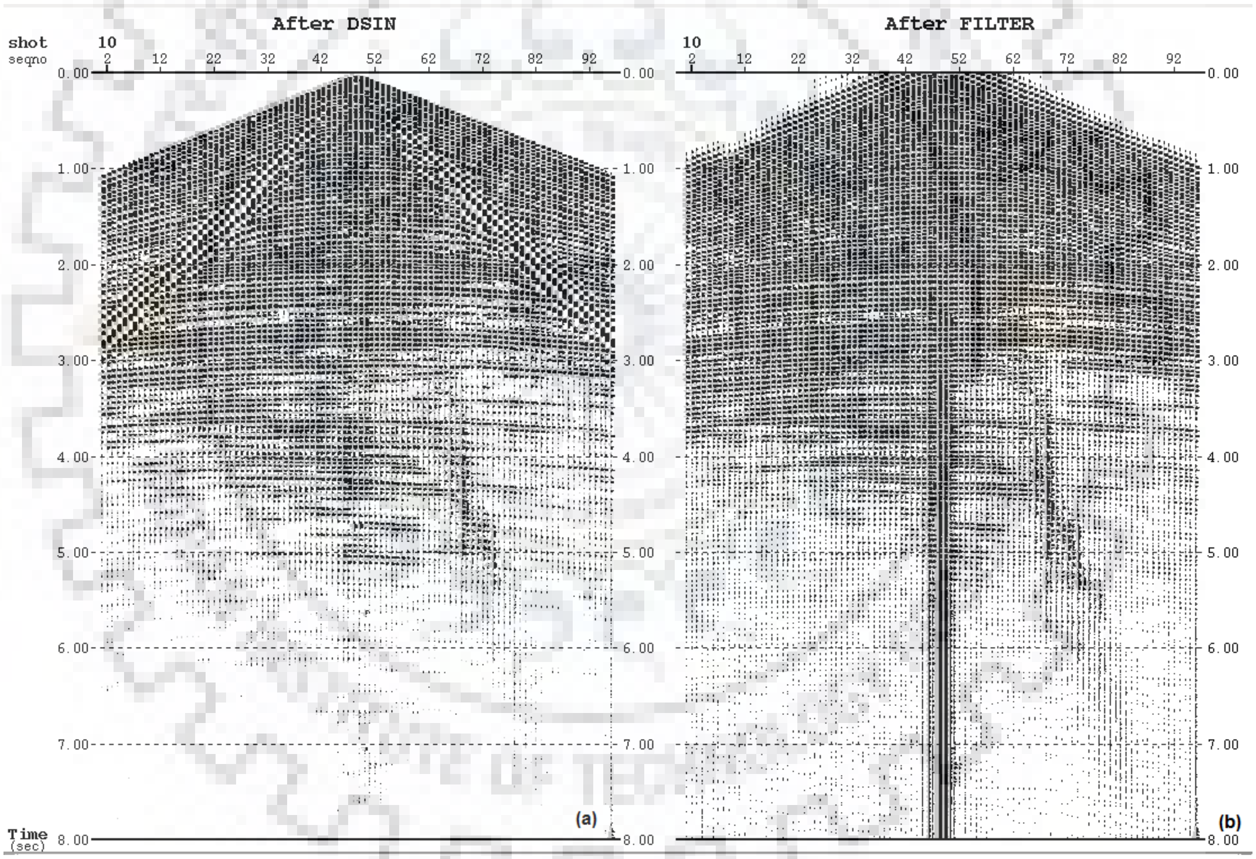
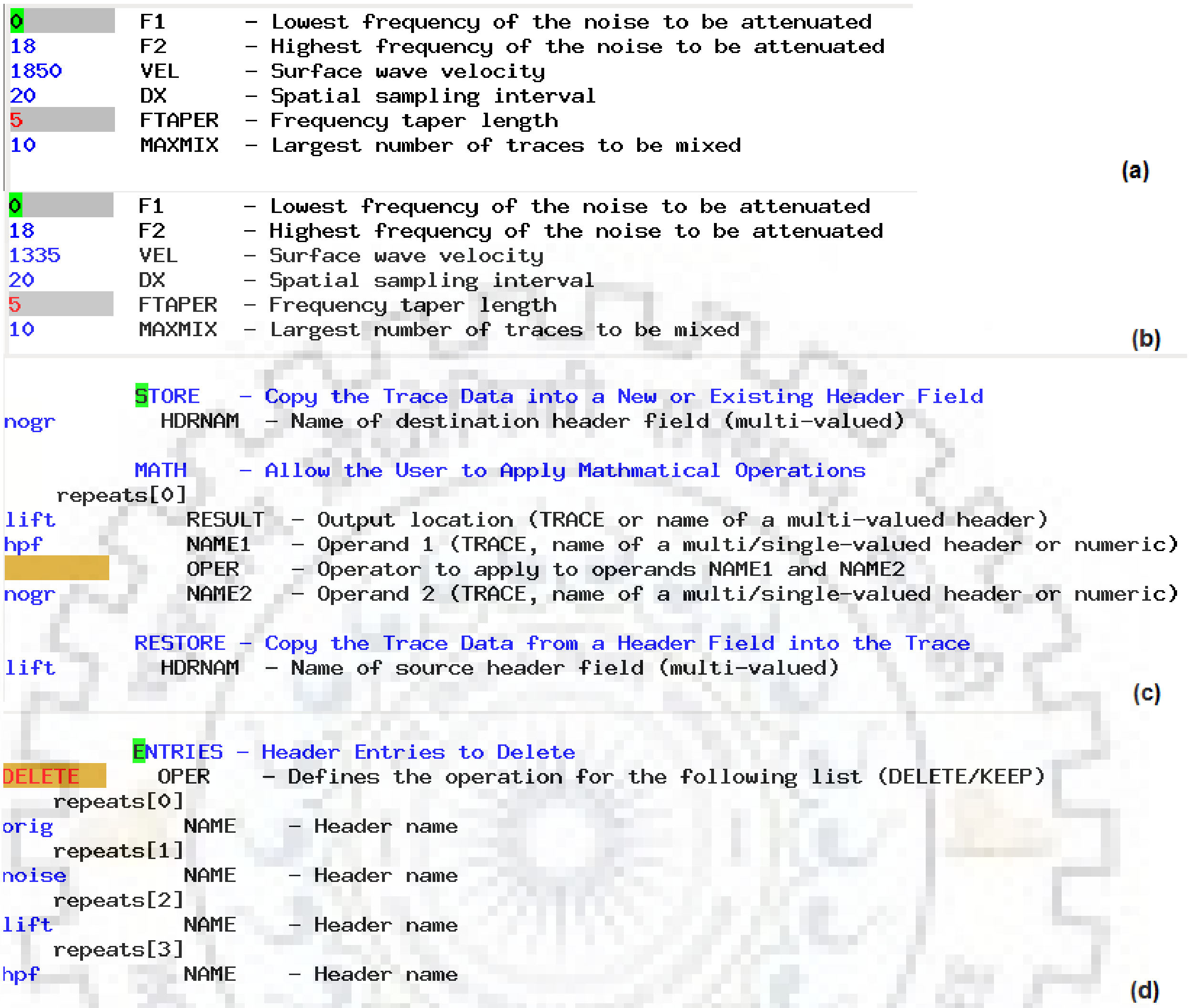


Figure-4.11 (a) Input shot gather (shot point-10) obtained after geometry merge (b) Shot gather obtained after FILTER module

As can be seen from Fig-4.11, a clear difference can be observed between the edited input shot gather and after applying FILTER module where the ground roll are reduced.



```
0            F1       - Lowest frequency of the noise to be attenuated
18           F2       - Highest frequency of the noise to be attenuated
1850         VEL      - Surface wave velocity
20           DX       - Spatial sampling interval
5            FTAPER   - Frequency taper length
10           MAXMIX   - Largest number of traces to be mixed
```

```
0            F1       - Lowest frequency of the noise to be attenuated
18           F2       - Highest frequency of the noise to be attenuated
1335         VEL      - Surface wave velocity
20           DX       - Spatial sampling interval
5            FTAPER   - Frequency taper length
10           MAXMIX   - Largest number of traces to be mixed
```

```
             STORE    - Copy the Trace Data into a New or Existing Header Field
nogr           HDRNAM  - Name of destination header field (multi-valued)

             MATH     - Allow the User to Apply Mathmatical Operations
    repeats[0]
lift              RESULT   - Output location (TRACE or name of a multi-valued header)
hpf               NAME1    - Operand 1 (TRACE, name of a multi/single-valued header or numeric)
                  OPER     - Operator to apply to operands NAME1 and NAME2
nogr              NAME2    - Operand 2 (TRACE, name of a multi/single-valued header or numeric)

             RESTORE - Copy the Trace Data from a Header Field into the Trace
lift           HDRNAM  - Name of source header field (multi-valued)
```

```
             ENTRIES - Header Entries to Delete
DELETE         OPER     - Defines the operation for the following list (DELETE/KEEP)
    repeats[0]
orig              NAME     - Header name
    repeats[1]
noise             NAME     - Header name
    repeats[2]
lift              NAME     - Header name
    repeats[3]
hpf               NAME     - Header name
```

Figure-4.12- (a) Parameters used in LFAF-1 module (b) Parameters used in LFAF-2 module (c) Parameters used in HDRMAN-3 (d) Parameters used in HEADDEL (all modules are corresponding to the flow of Ground roll job)

To further improve the results done by bandpass filtering, another approach was taken where the velocity corresponding to the ground roll is used to identify, using LFAF module (Fig. 4.12), and the part of signal which concur with ground roll in the data and is removed using HDRMAN module.

LFAF attenuates surface-wave noise via low-frequency array forming. Algorithm transforms the data from the time-space domain to the frequency-space domain with the help of surface velocity and frequency band provided by the user. Next, each frequency component is convolved with a boxcar function, which is the appropriate calculated array to remove the noise train with the help of specified velocity. Frequency components outside the specified frequency band remain constant and data transformed back to the time-space domain.

Velocities for surface waves to be used in LFAF module are picked as 1850 ms^{-1} and 1350 ms^{-1} after some trials. Another module of HDRMAN (HDRMAN-3) was used to maneuver the data further. As can be seen in Fig-4.12 (c), ***nogr*** header field is created and subtracted from ***hpf*** file to give output named ***lift.***

Next, HEADDEL is used to delete the entries namely, ***orig, noise, lift*** and ***hpf.*** The primary function of HEADDEL is to delete entries from seismic trace headers. The user supplies to the program the names of the header entries to be deleted. Any number of header entries may be designated for deletion. Error messages are issued if the user supplies the name of the primary sort key or the names of any essential entries, such as type, lasttr or seqno. The program informs the user that these cannot be deleted and it does not delete them. An error message is also issued if the user supplies the name of a nonexistent header entry. HEADDEL automatically produces an edit phase listing of all header entries both before and after deletions. The listing of header entries does not include values.The program will not delete the primary sort key, lasttr, seqno or type from the trace headers.HEADDEL output is traces, with user-specified header entries deleted, are passed on for further processing. A list of trace header entries is printed.

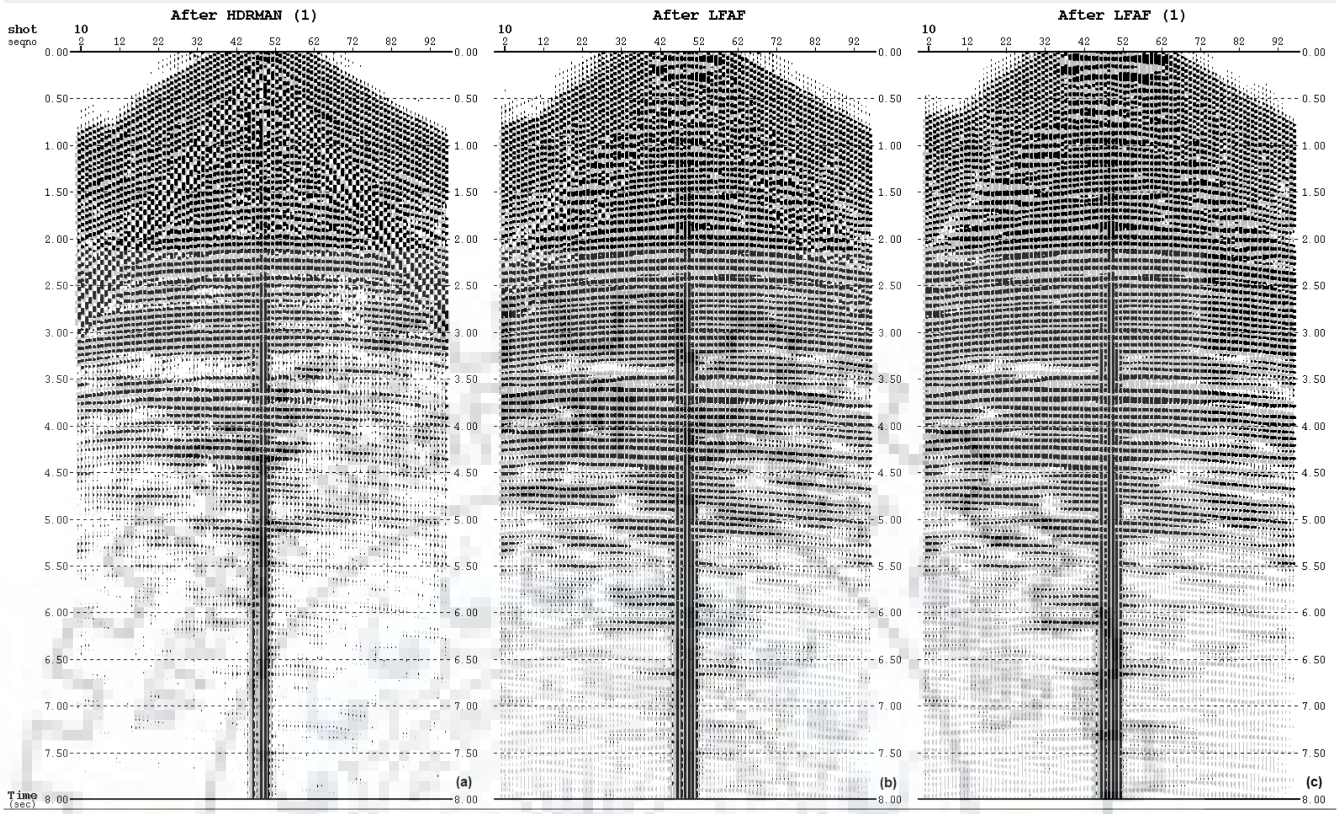


Figure-4.13 (a) Output after HDRMAN-1 (b) Output after LFAF-1 (c) Output after LFAF-2

Figure-4.13 (a) shows the shot gather just after HDRMAN-1 after taking using FILTER module using bandpass filtering while Fig-4.13 (b) & (c) shows the same shot point after processing through LFAF-1 and LFAF-2 respectively. Ground rolls can be clearly observed in Fig-4.13 as a trend (straight line with mild slope) different from usual hyperbolas observed in land seismic data. These are stored in header files are subtracted with the help of HDRMAN module.

Because of some of the modules, unwanted noise may have been amplified which are to be removed. One easy solution is to use MUTE module to remove the amplified signal. The same mute file can also be used that was used during editing.

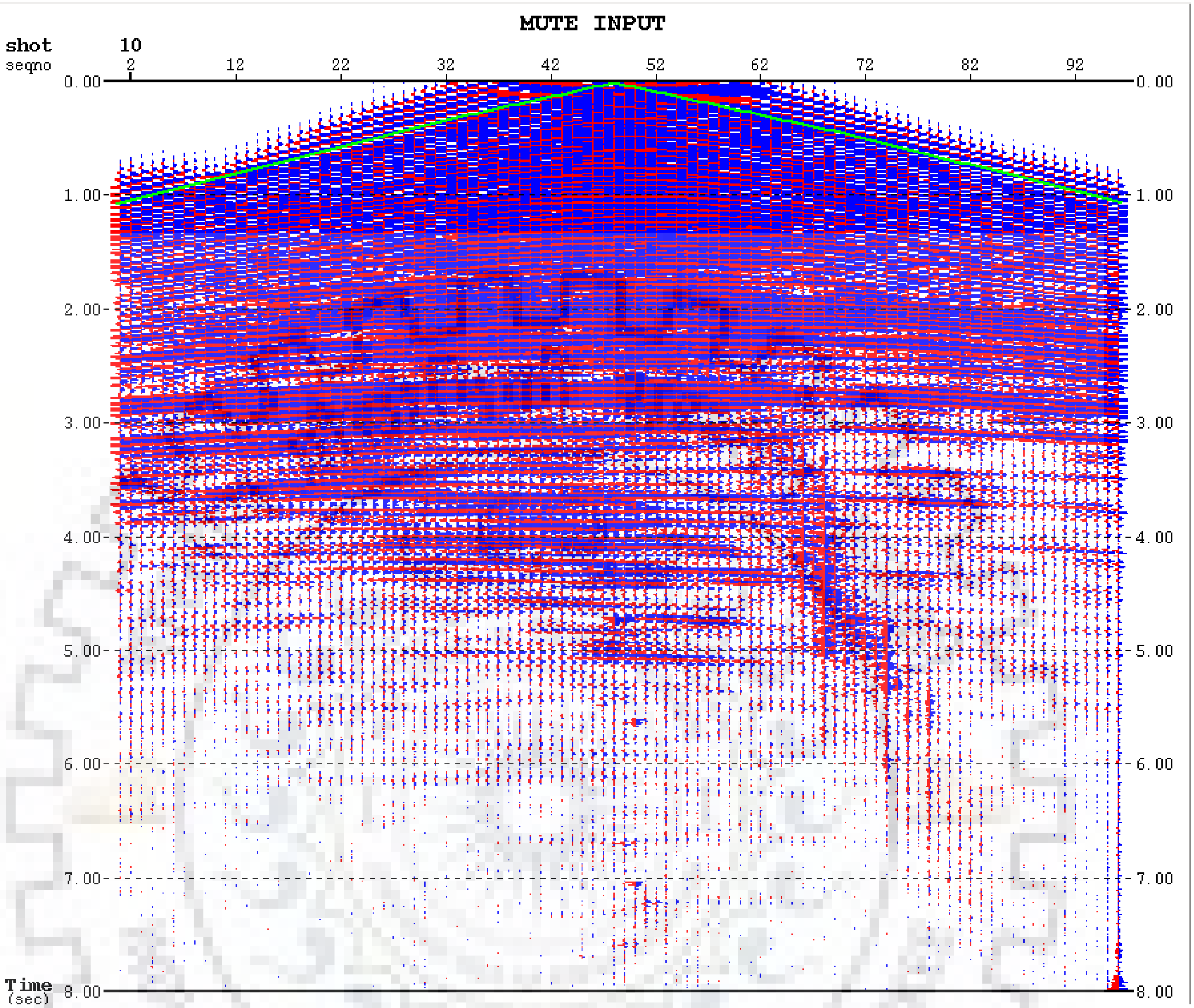


Figure-4.14- MUTE module is used to apply mute

Fig-4.14 shows the marking of mute to remove the artefacts introduced. This step is necessary as the artefacts may distort the real signal during the later stages of processing, if not removed.

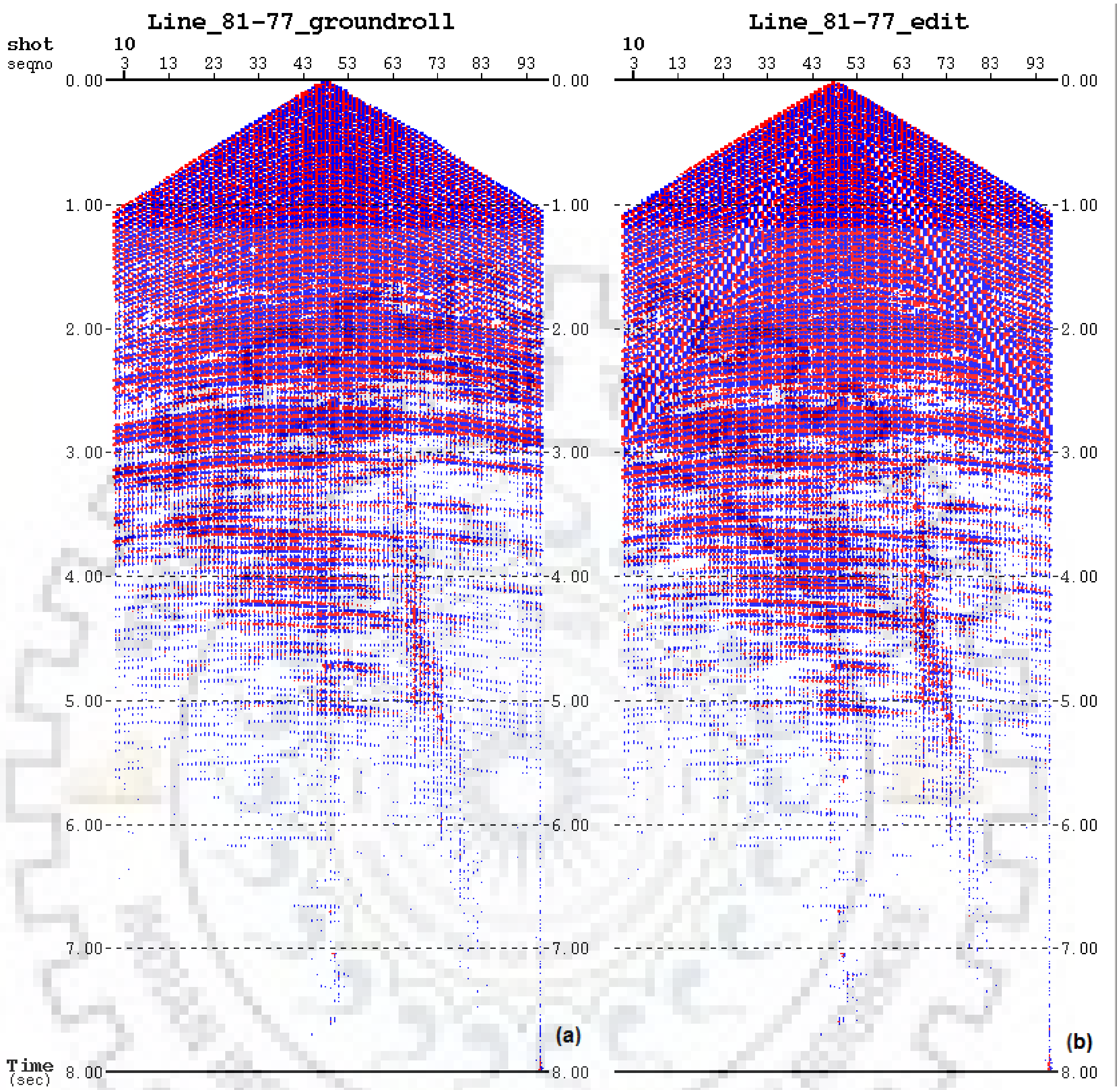


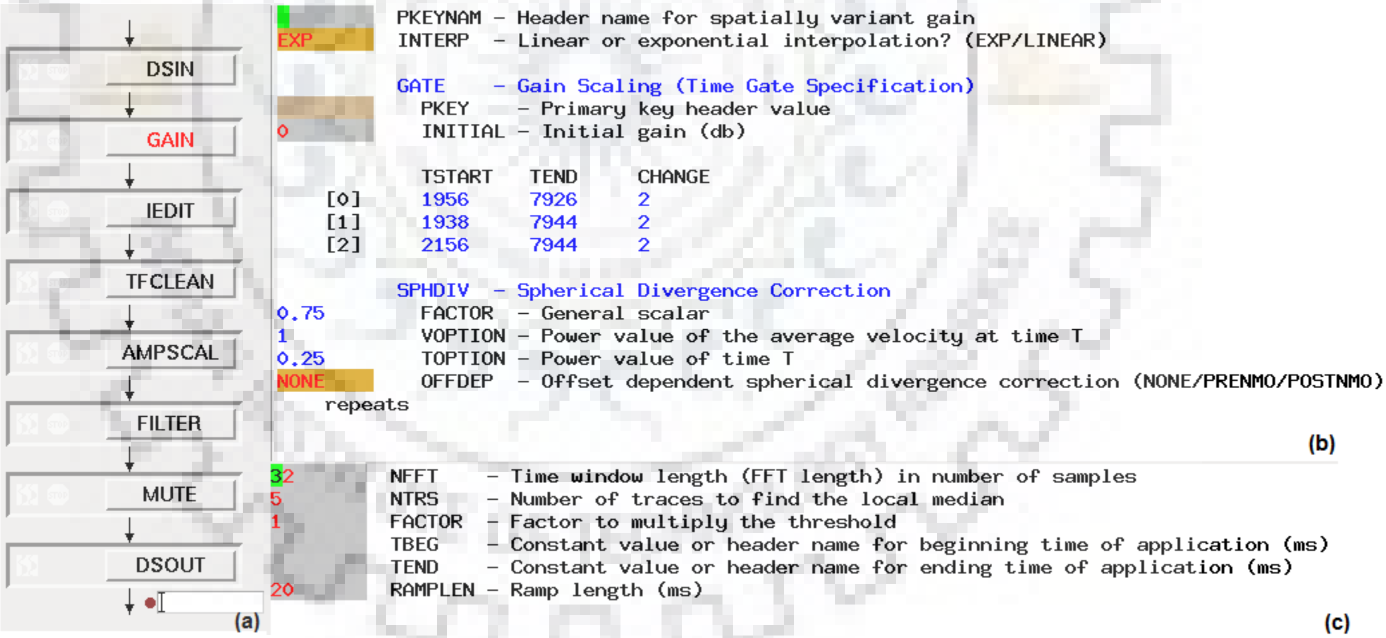
Figure-4.15 (a) Final output after Ground roll job (b) Input shot gather after editing

Comparing Fig- 4.15 (a) and (b), the processing flow has successfully removed the ground roll from the data. Ground roll, if not removed, distorts the signal and masks over the primaries hindering the processing. The stack created from data from which ground roll is not removed is very distorted (Yilmaz, 2001).

4.1.5 Preprocessing

Before carrying out deconvolution, the data must be processed such that all the events must be clear and deep-seated reflection can be seen. Because of spherical divergence and attenuation of high frequency signal by Earth, much of the reflections from the deeper part of section are weaker as compared to shallow depth reflections. This is due to decrease in wave strength (energy per unit area of wave front) with distance as a result of geometric spreading. To amplify and enhance these deep-seated reflections, the strength of amplitude corresponding to these reflections needs to be increased without affecting the upper part of signal. For all of these purposes, preprocessing is carried out.

In Paradigm, the following processing flow is employed (Fig. 4.16).



```
        PKEYNAM - Header name for spatially variant gain
EXP     INTERP  - Linear or exponential interpolation? (EXP/LINEAR)

        GATE    - Gain Scaling (Time Gate Specification)
          PKEY    - Primary key header value
0         INITIAL - Initial gain (db)

          TSTART    TEND      CHANGE
    [0]   1956      7926      2
    [1]   1938      7944      2
    [2]   2156      7944      2

        SPHDIV  - Spherical Divergence Correction
0.75      FACTOR  - General scalar
1         VOPTION - Power value of the average velocity at time T
0.25      TOPTION - Power value of time T
NONE      OFFDEP  - Offset dependent spherical divergence correction (NONE/PRENMO/POSTNMO)
    repeats
```

```
32      NFFT    - Time window length (FFT length) in number of samples
5       NTRS    - Number of traces to find the local median
1       FACTOR  - Factor to multiply the threshold
        TBEG    - Constant value or header name for beginning time of application (ms)
        TEND    - Constant value or header name for ending time of application (ms)
20      RAMPLEN - Ramp length (ms)
```

Figure-4.16 (a) Processing Flow used for Preprocessing (b) Parameters used in GAIN module (c) Parameters used in TFCLEAN module

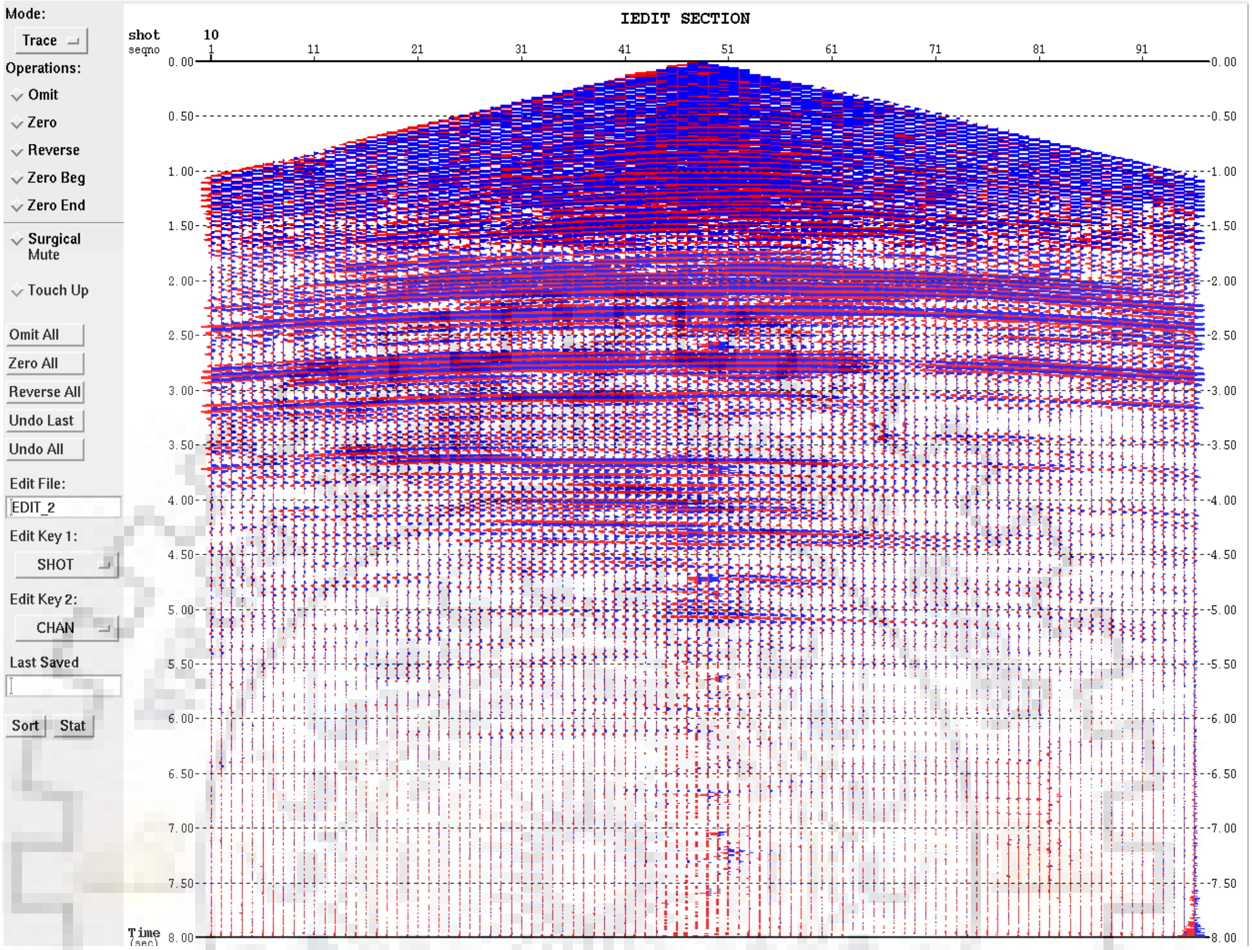
The module GAIN provides a method of balancing seismic trace amplitude by applying a time-variant exponential or linear scalar to a set of data. GAIN can also be used to apply or remove offset independent or dependent spherical divergence corrections. Spherical divergence corrections can be applied either as an additional or alternative gain option.

The module GAIN consists of three options for specifying the application of a scalar and a spherical divergence correction option given as-

1. GATE-For traces in a designated ensemble, the user specifies a gate, or gates, composed of a beginning sample time (parameter TSTART) and an ending sample time (parameter TEND).
2. PGAIN-The user first specifies a series of GAIN values, in decibels. Then an ensemble of traces is designated with PKEY and a series of trace sample times. It is to these traces at the specified times that the GAIN values are applied. It is possible to apply one set of GAIN values to more than one ensemble of traces.
3. PAIRS-For this option, the user simply designate an ensemble of traces (PKEY), a trace sample time (TIME) and the gain value (GAIN), in decibels, to be applied at the time. The TIME, GAIN pairs may be repeated as many times as desired for a particular PKEY. The PAIRS parameters may be submitted for as many PKEYs as desired.

After many trials with different values for FACTOR, VOPTION and TOPTION, the values finally used is useful in optimally removing geometrical spreading while avoiding to introduce unnecessary noise.

A positive scalar can be specified to compensate for the decay of signal energy that occurs as reflection time increases. With a negative scalar, it is possible to remove previously applied gain. Spherical divergence corrections are usually applied to seismic data to compensate for decrease in seismic wave amplitude due to geometrical spreading of the wavefront. The decrease in amplitude occurs as the distance of the signal from the energy source increases.



Mode: Trace

Edit File: EDIT_2

Edit Key 1: SHOT

Edit Key 2: CHAN

Last Saved:

Figure-4.17- Shot gather viewed in Interactive mode for the processing in IEDIT module

IEDIT applies the seismic data edits that have been stored in a file in the database during a session with the Interactive IEDIT program. In IEDIT, each of the trace is observed individually for noise bursts or polarity change. Any irregularity specific to a shot gather can be removed with the help of IEDIT module by using operations like Omit, Zero, Reverse, Zero Beg, Zero End, Surgical Mute and Touch up. Touch up smoothens the amplitude of ensemble traces picked and is important in removing noise burst (Fig. 4.17).

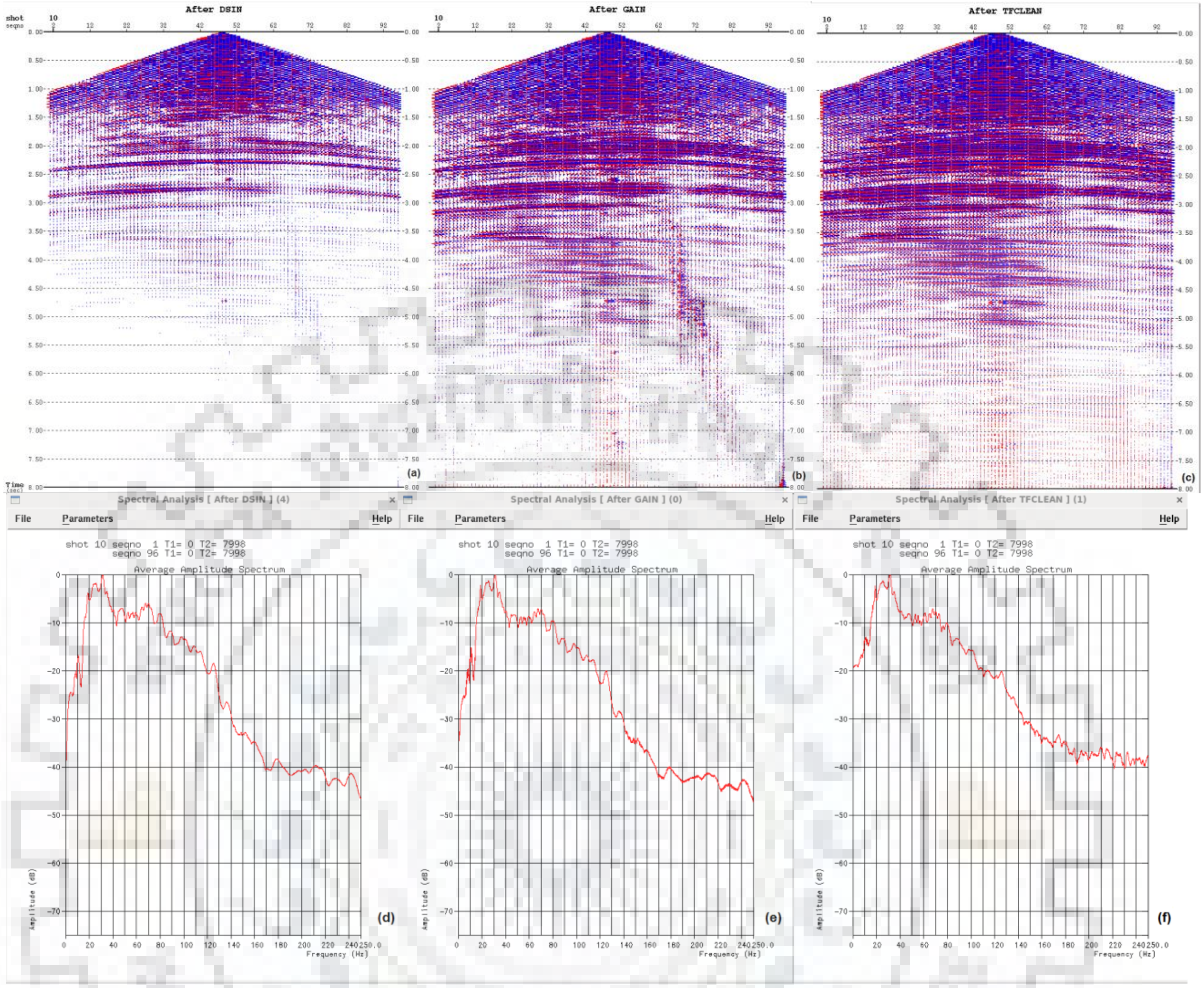
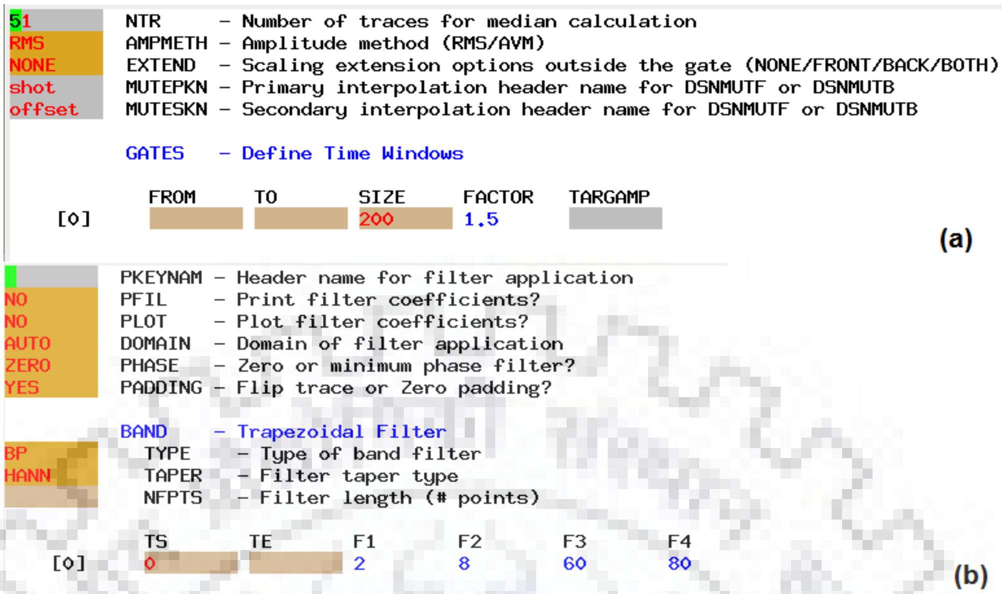


Figure-4.18- (a)Input shot gather obtained after Groundroll job (b) Shot gather after applying GAIN module (c) Shot gather after applying TFCLEAN module (d) Amplitude Spectrum corresponding to the input (DSIN) (e) Amplitude Spectrum corresponding to GAIN (f) Amplitude Spectrum corresponding to TFCLEAN

Comparing both the images in Fig-4.18 (a) and (b), it can be observed that more and more deep-seated reflections are much clearer after applying GAIN module. For furthermore enhancing TFCLEAN and AMPSCALE modules are applied. Noises that can be observed at the lower part of section of Fig-4.18 (b) are removed successfully with the help of TFCLEAN and IEDIT module and Fig-4.18 (c) shows the result of these modules accordingly. TFCLEAN performs noise suppression in the time-frequency domain. This module is effective in eliminating the noise bursts in gathers without affecting nearby samples and/or traces. The noise suppression is applied sample by sample on various frequency components of the data resulting in a clean dataset with nicely balanced spectra.

TFCLEAN may be used as an automatic method of suppressing noise bursts in seismic records. Each input gather is transformed to time-frequency (TF) domain by using Fast Fourier Transforms within short time windows centered on each input sample. TF transform allows filtering of the noise in a much localized way both in terms of time and frequency with the use of sub banded TF attributes of the data. Short time windows are specified by the NFFT parameter, and since a Fast Fourier Transform will be performed NFFT must be a number corresponding to an integer power of 2. A short, sliding window of NFFT samples, with a Gaussian weighting function, will be centered on each input sample prior to the Fourier Transform. The noise suppression will be done only in the frequency sub bands and in the time zones specified by the user.

Time-Frequency Transform describes the energy density of a signal simultaneously in time and frequency. The mapping process from signal space to the time-frequency plane requires the seismic trace to be decomposed into several different discrete frequency components within small running time gates. The module uses Fast Fourier Transform in small running windows to build up an output time-frequency spectrum for each input trace.



```
51      NTR      - Number of traces for median calculation
RMS     AMPMETH  - Amplitude method (RMS/AVM)
NONE    EXTEND   - Scaling extension options outside the gate (NONE/FRONT/BACK/BOTH)
shot    MUTEPKN  - Primary interpolation header name for DSNMUTF or DSNMUTB
offset  MUTESKN  - Secondary interpolation header name for DSNMUTF or DSNMUTB

        GATES    - Define Time Windows

             FROM       TO         SIZE       FACTOR     TARGAMP
    [0]                            200        1.5
```

```
        PKEYNAM - Header name for filter application
NO      PFIL    - Print filter coefficients?
NO      PLOT    - Plot filter coefficients?
AUTO    DOMAIN  - Domain of filter application
ZERO    PHASE   - Zero or minimum phase filter?
YES     PADDING - Flip trace or Zero padding?

        BAND    - Trapezoidal Filter
BP        TYPE    - Type of band filter
HANN      TAPER   - Filter taper type
          NFPTS   - Filter length (# points)

          TS         TE         F1         F2         F3         F4
    [0]   0                     2          8          60         80
```

Figure-4.19 (a) Parameters used in AMPSCAL (b) Parameters used in FILTER

After TFCLEAN module, AMPSCAL, using parameters given in Fig-4.19, is applied to remove the effect of attenuation. AMPSCAL is designed to attenuate noise bursts, cable slashes, air blasts, and frost breaks. The data are analyzed across small overlapping spatial and temporal windows by comparing the window amplitude with the amplitude of corresponding window on neighboring traces in the dataset. Windows with anomalously high amplitudes are scaled down.

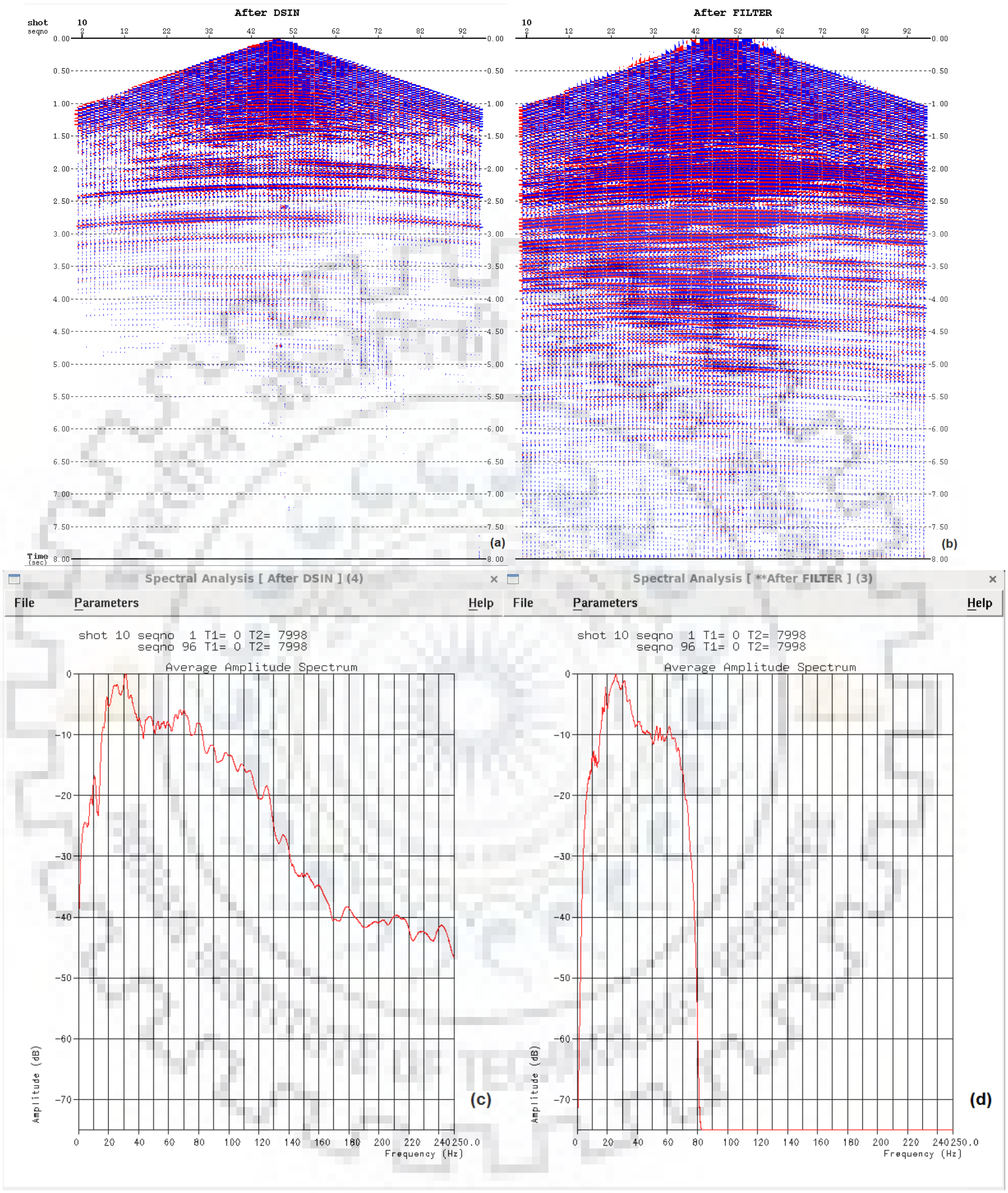
For each trace, for each gate a median RMS or AVE amplitude is found from the amplitudes of corresponding gates in the NTR neighboring traces in the dataset. Only nonzero samples are used in the computation of the amplitudes. The median is compared to the gate amplitude in the trace. If the trace gate amplitude exceeds threshold amplitude, the trace gate is scaled down to specified target amplitude. The threshold is the median multiplied by FACTOR. The target amplitude which the data will be scaled to is the median multiplied by TARGAMP. TARGAMP equal 0.0 will result in zeroing the output in the gate.

One ought to select the window size to be equal to one length of the noise problem, normally about 200 ms. since the run time depends on the number of windows, use large windows where there are no significant noise problems and use smaller windows where the data become noisy.

FILTER is applied with bandpass filtering employed to smoothen the effect of TFCLEAN and AMPSCAL on the data.

The purpose of enhancing the deeper reflections and removing the effects of attenuation and geometric spreading is achieved with this job successfully. Comparing both the images of Fig-4.20, it can be observed that the following flow has achieved the objective set for.

If we compare Fig-18 (d) and Fig-4.20 (c), the amplitude spectrum has changed at a great extent. The main aim to analyze the amplitude spectrum is to get a flat spectrum ideally but this is not always possible. Thus, the data is altered to an extent that a function as close to flat spectrum is obtained. Another thing to keep in mind is that bandwidth of the data needs to be restored while analyzing the spectrum. Thus, FILTER module is designed in such a way that both of these objectives are achieved.



```
shot 10 seqno  1 T1= 0 T2= 7998
        seqno 96 T1= 0 T2= 7998
```

```
shot 10 seqno  1 T1= 0 T2= 7998
        seqno 96 T1= 0 T2= 7998
```

Figure- 4.20 (a) Input shot point gather (b) Output after applying FILTER module (c) Amplitude Spectrum corresponding to input (d) Amplitude Spectrum corresponding to FILTER

4.1.6 F-K filtering

After Preprocessing is done, the data still might contain some noise which can be removed using F-K filtering. In F-K filtering, the data is transformed into frequency-wavenumber domain from time-offset domain. This transformation helps in identifying those noisy parts of traces which were undetectable before.

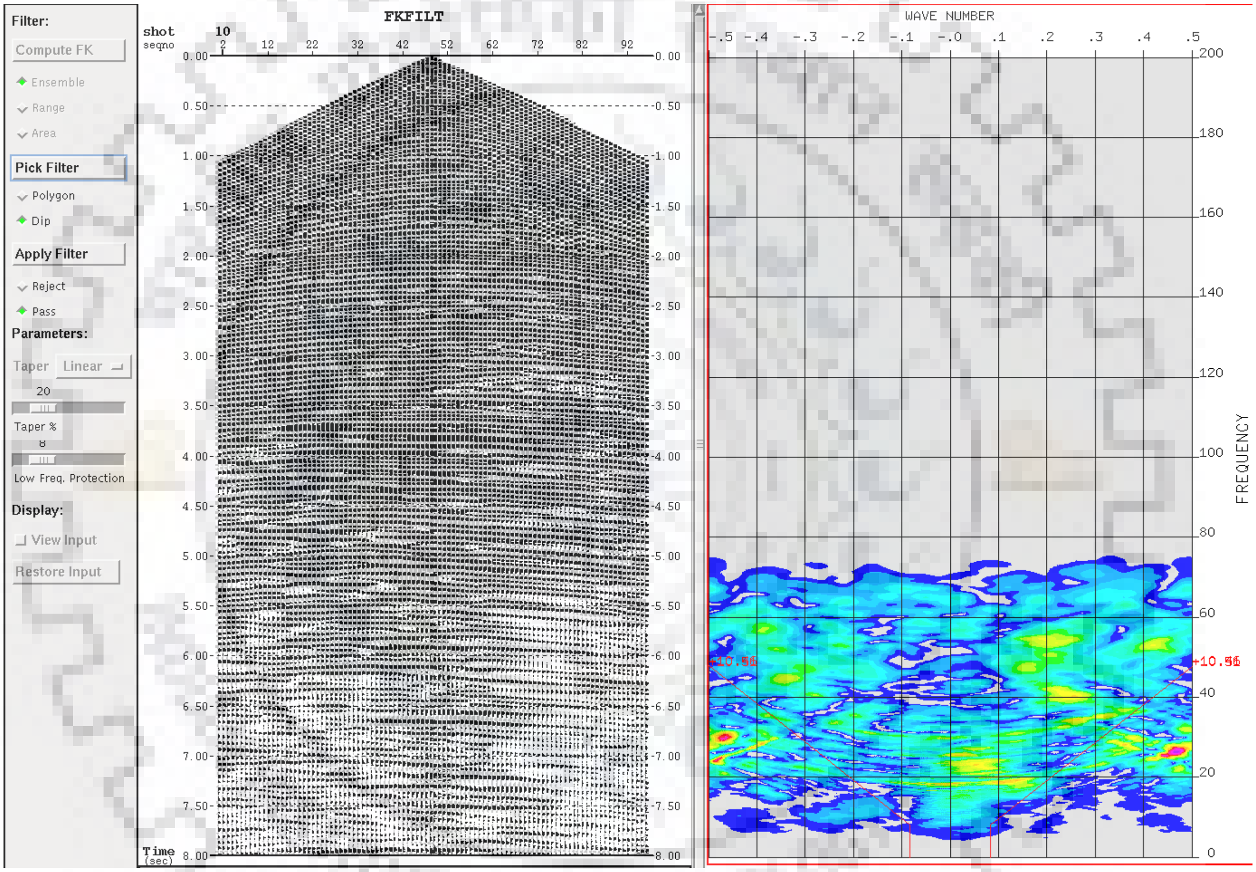


Figure-4.21- F-K Filter module in interactive mode

The function of FKFILT is to design and apply 2D f-k domain filters on unstacked data. FKFILT incorporates the functionalities of FKBUILD and FKAPPLY into a single module. FKFILT generates pass or reject filters. The user may specify multiple filters to be merged into a final filter for application in one pass. Filters may be specified by two alternate methods: specified as the vertices of a polygon in f-k space or they may be specified by pairs of dip parameters, in units of milliseconds per trace.

F-K filter is used in interactive mode by selecting the filter (Dip or Polygon) using the wave number-frequency graph. As can be seen in Fig-4.21, the spectrum corresponding to shot point is represented in colour scheme on the right side of the image. Dip type of picking is used in order to remove the part corresponding to noise (red to yellow) from the signal.

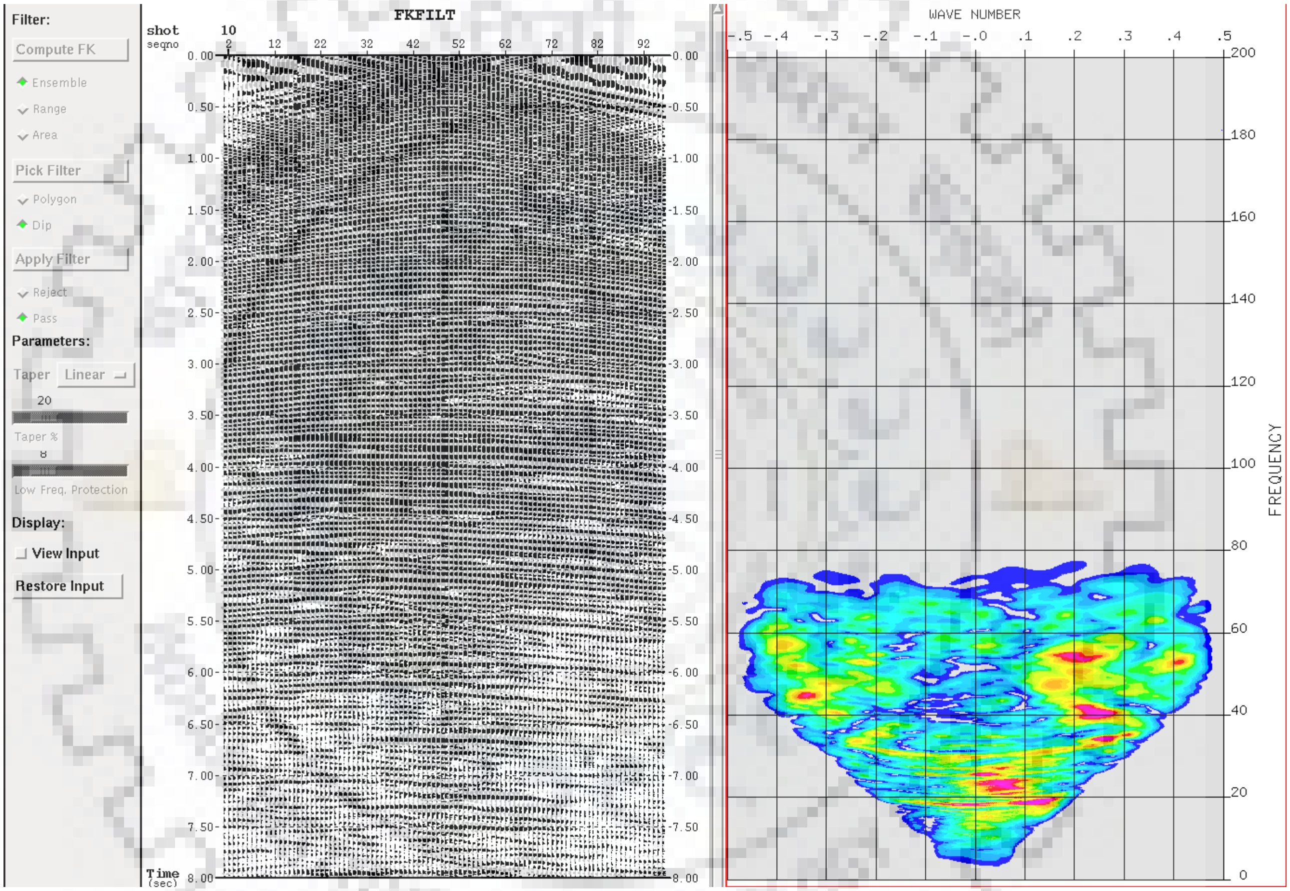


Figure-4.22- F-K Filter module in interactive mode after applying the filter

Fig-4.22 corresponds to the same shot point for which the filter has been applied. After applying the f-k filter, MUTE module is used to remove the unnecessary amplified signal.

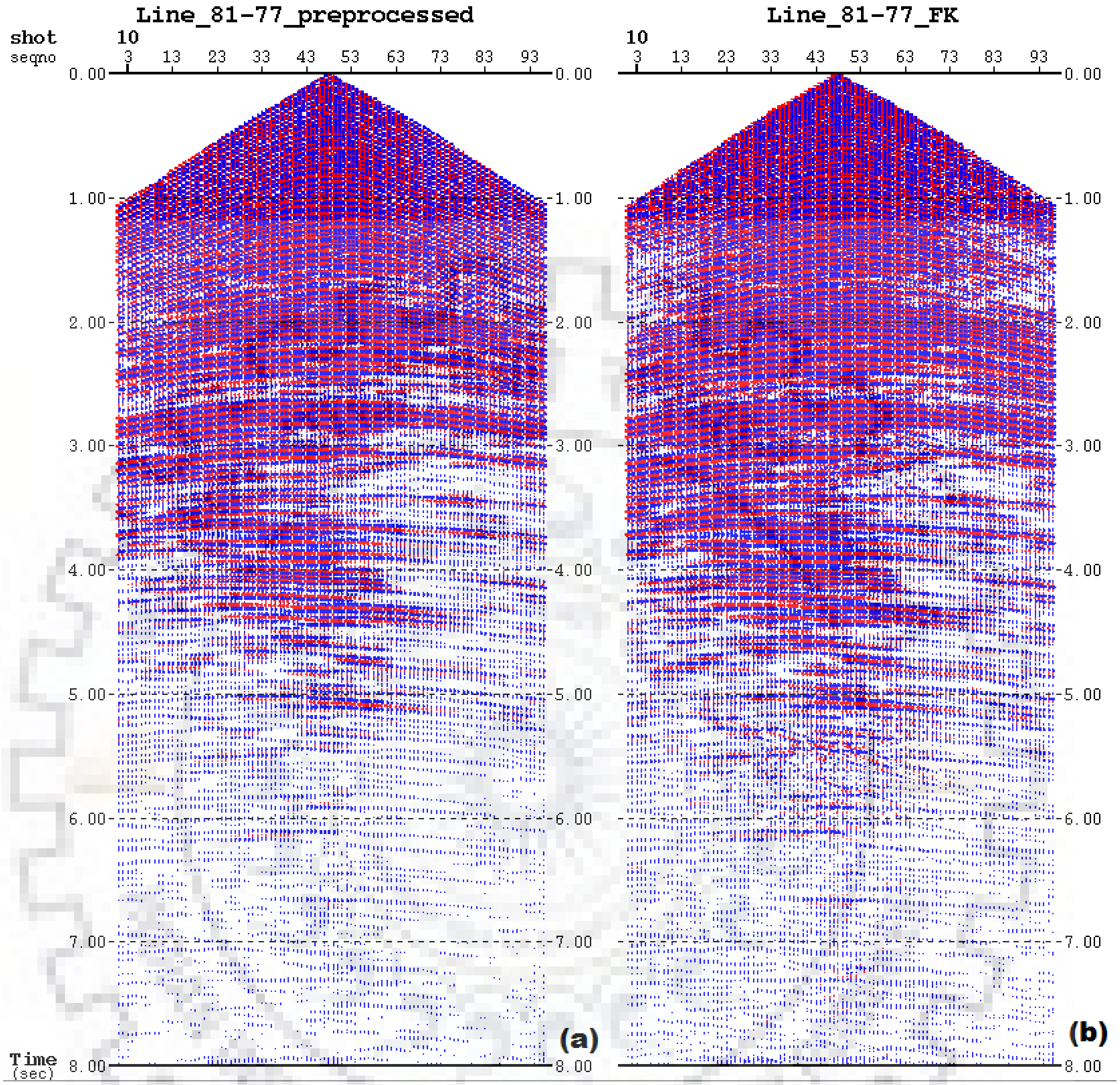
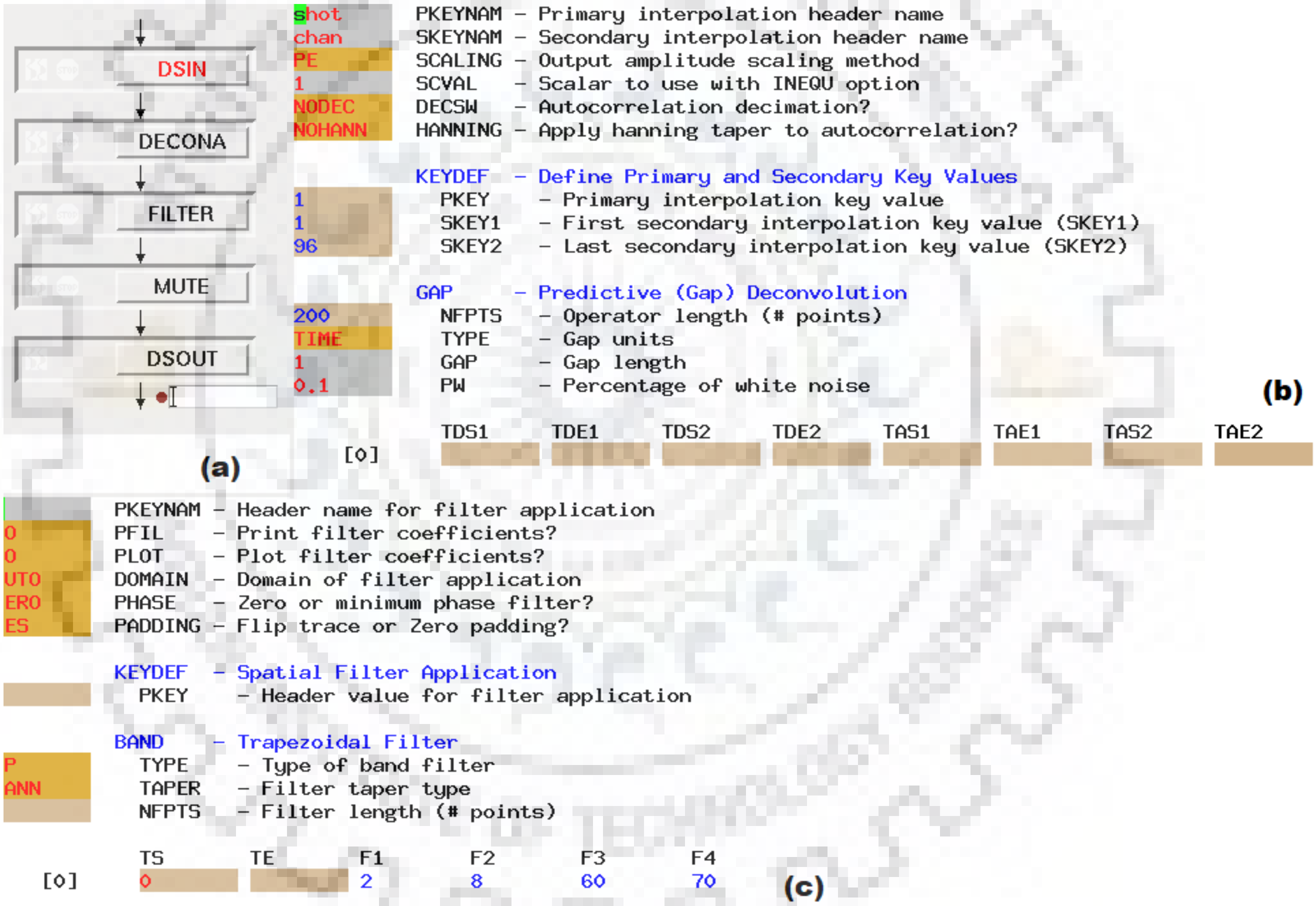


Figure-4.23 (a) Input shot gather for f-k filter job (b) Output after applying FKFILTR and MUTE module

A better and clear image of shot gather can be observed in Fig-4.23 (b) after applying f-k filter to the preprocessed data.

4.1.7 Deconvolution

One of the most important processes to be carried out during the processing of seismic data is Deconvolution. There are many different modules in Paradigm which are used to apply different types of deconvolution. In this case, though DECONA module was used for processing (Fig-4.24a). DECONA designs and applies deconvolution filters to seismic traces. It uses the Wiener-Levinson algorithm to sharpen seismic events and extend the frequency bandwidth.



```
shot     PKEYNAM - Primary interpolation header name
chan     SKEYNAM - Secondary interpolation header name
PE       SCALING - Output amplitude scaling method
1        SCVAL   - Scalar to use with INEQU option
NODEC    DECSW   - Autocorrelation decimation?
NOHANN   HANNING - Apply hanning taper to autocorrelation?

         KEYDEF  - Define Primary and Secondary Key Values
1          PKEY    - Primary interpolation key value
1          SKEY1   - First secondary interpolation key value (SKEY1)
96         SKEY2   - Last secondary interpolation key value (SKEY2)

         GAP     - Predictive (Gap) Deconvolution
200        NFPTS   - Operator length (# points)
TIME       TYPE    - Gap units
1          GAP     - Gap length
0.1        PW      - Percentage of white noise

           TDS1  TDE1  TDS2  TDE2  TAS1  TAE1  TAS2  TAE2
   [0]
```

```
      PKEYNAM - Header name for filter application
O     PFIL    - Print filter coefficients?
O     PLOT    - Plot filter coefficients?
UTO   DOMAIN  - Domain of filter application
ERO   PHASE   - Zero or minimum phase filter?
ES    PADDING - Flip trace or Zero padding?

      KEYDEF  - Spatial Filter Application
        PKEY    - Header value for filter application

      BAND    - Trapezoidal Filter
P       TYPE    - Type of band filter
ANN     TAPER   - Filter taper type
        NFPTS   - Filter length (# points)

        TS    TE    F1    F2    F3    F4
  [0]   0           2     8     60    70
```

Figure-4.24- (a) Processing flow for Deconvolution (b) Parameters used in DECONA module (c) Parameters used in FILTER module

As can be seen from Fig-4.24 (b), Predictive deconvolution is used with the help of GAP operator while defining the primary and secondary key with KEYDEF. KEYDEF operator is necessary to in order to use any other operator in DECONA module.

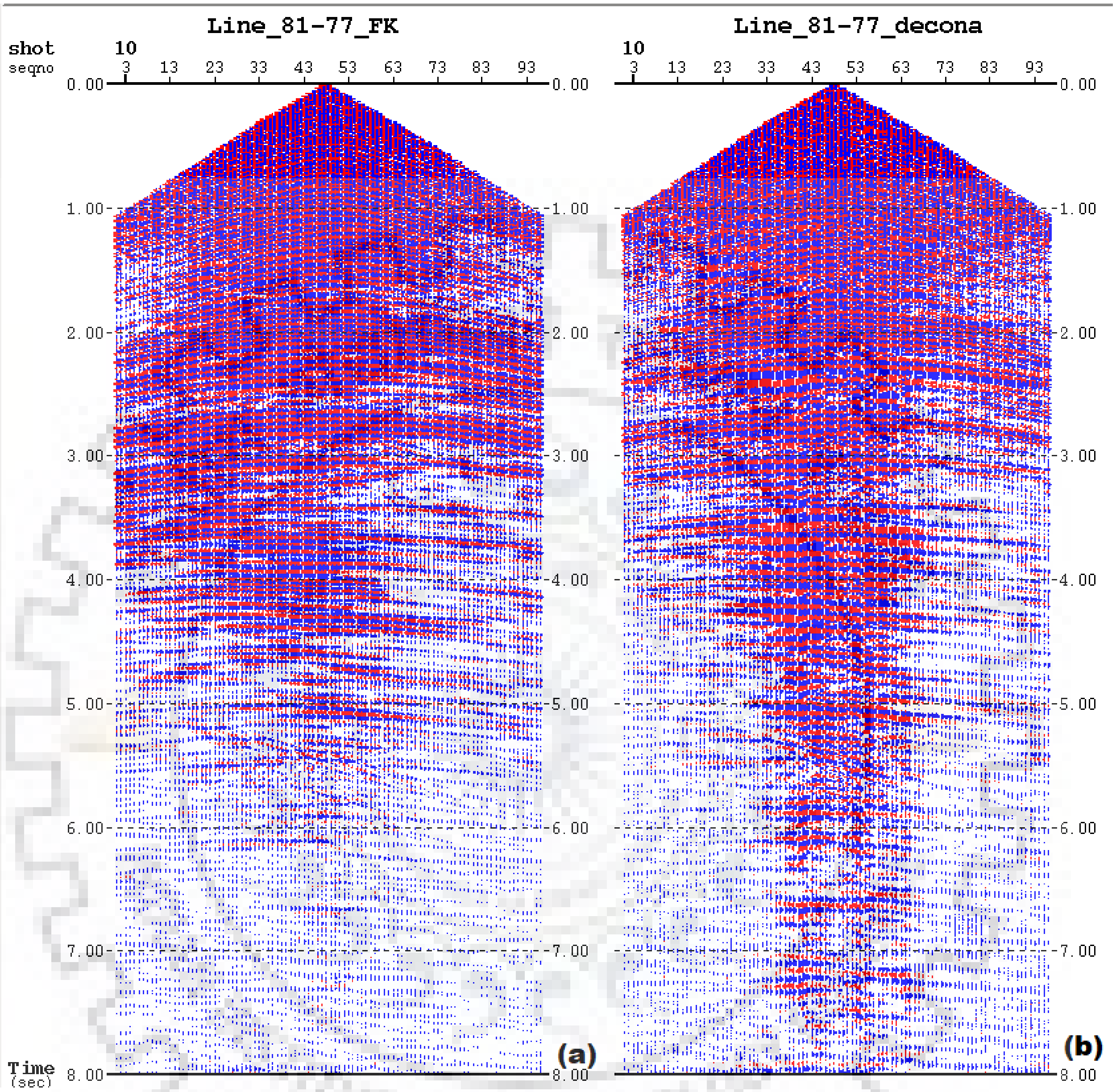
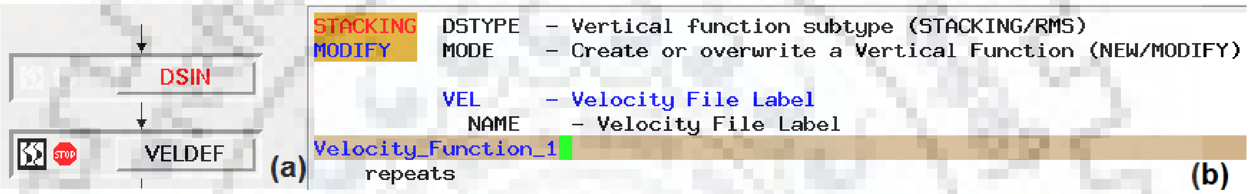


Figure- 4.25- (a) Input shot gather to Deconvolution job (b) Output after Deconvolution job

The output, as can be seen in Fig-4.25 (b), has better deep seated reflections than the input of Deconvolution job.

4.1.8 Velocity Analysis

For Velocity analysis, the data which was in shot gather was sorted into CDP gather. Velocity analysis in Paradigm can be carried out in two ways, either Velocity navigator in Paradigm can be used for interactive picking of velocity or VELDEF module can be used in ECHOS. In this case, VELDEF was used for velocity picking (Fig. 4.26). VELDEF stores velocity and depth/time functions in the seismic database. VELDEF does not process the seismic data. The functions are in the form of time/velocity pairs or time/depth pairs defined by the user.



```
STACKING  DSTYPE  - Vertical function subtype (STACKING/RMS)
MODIFY    MODE    - Create or overwrite a Vertical Function (NEW/MODIFY)

          VEL     - Velocity File Label
            NAME    - Velocity File Label
Velocity_Function_1
    repeats
```

Figure-4.26 (a) Processing flow to create velocity function (b) Parameters used in VELDEF

Velocity is defined with the help of VELDEF module by using VEL operator used to label and store velocity function which in this case is “Velocity_Function_1” and this velocity is stored in VELDEF. Programs that require velocity or depth functions perform such tasks as normal move out correction, migration, and stretch muting. Most of the programs that use the functions require they be stored in the database. Some of the programs that access database functions are NMO, MIGRATX, MIGRATE, MIGFK, MIGTX, MUTE (for stretch muting), and TOPLBL.

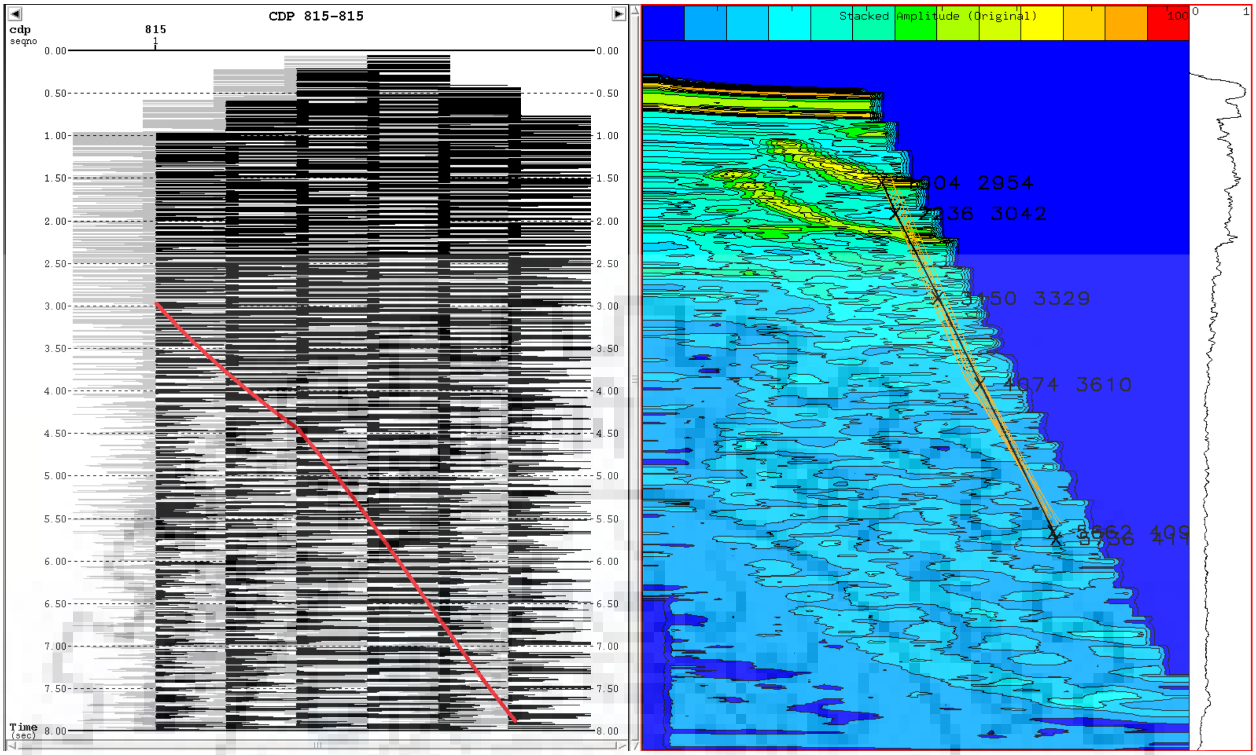


Figure-4.27-On left side is CDP traces and on right side is coherence curve corresponding to those CDP traces

Velocity is picked by where the coherence is high (red to yellow colour). These picks are picked in such a way that a trend in CDP traces can be seen which may correspond to horizons. The red trend in Fig-4.27 in CDP traces is marked horizon corresponding to the first pick of velocity in the coherence spectrum in same figure (Fig-4.27) (right side). In this way, at regular intervals of CDP gather, velocity is picked. The velocity is interpolated for the traces in between the intervals.

Next step is to apply mute for NMO stretching. Similar to picking, muting is also done to each CDP trace at regular interval and the mute is interpolated in between those intervals.

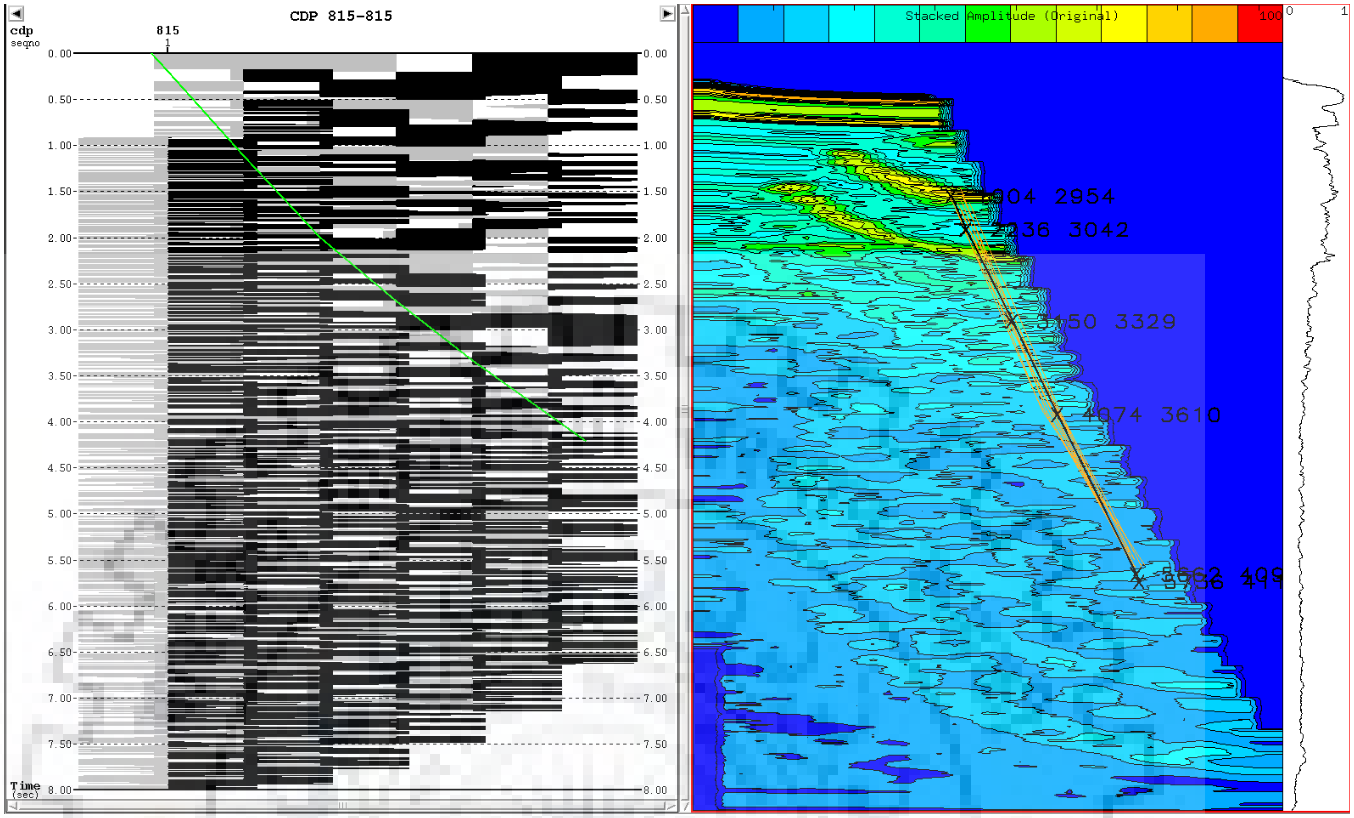


Figure- 4.28- Mute as applied in green line to NMO stretched CDP trace same as Fig-4.27

Mute is applied after analyzing the NMO stretch to CDP trace to get the optimum amount of data without including the stretch (Fig. 4.28).

In Vertical Function on main Paradigm window, the velocity function is used to create velocity section in order to create brute stack. The picking is done as stacking velocity but for migration RMS velocity is required which is also obtained from Vertical Function.

The Vertical Functions window is an interactive application you can launch directly from the Paradigm Session Manager. It offers a customizable, multi-panel graphic display of vertical function data including seismic data, well log data, and cross plot relationships. Vertical function data comprises a set of points, each of which marks the velocity at a given time or depth. The Vertical Function Data Manager provides a global view of all the vertical functions and pencil data in a project. Different velocity type can be found Stacking Velocity, RMS Velocity, Interval Velocity, and Average Velocity. Vertical function data is created automatically or semi-automatically by Paradigm seismic data processing applications.

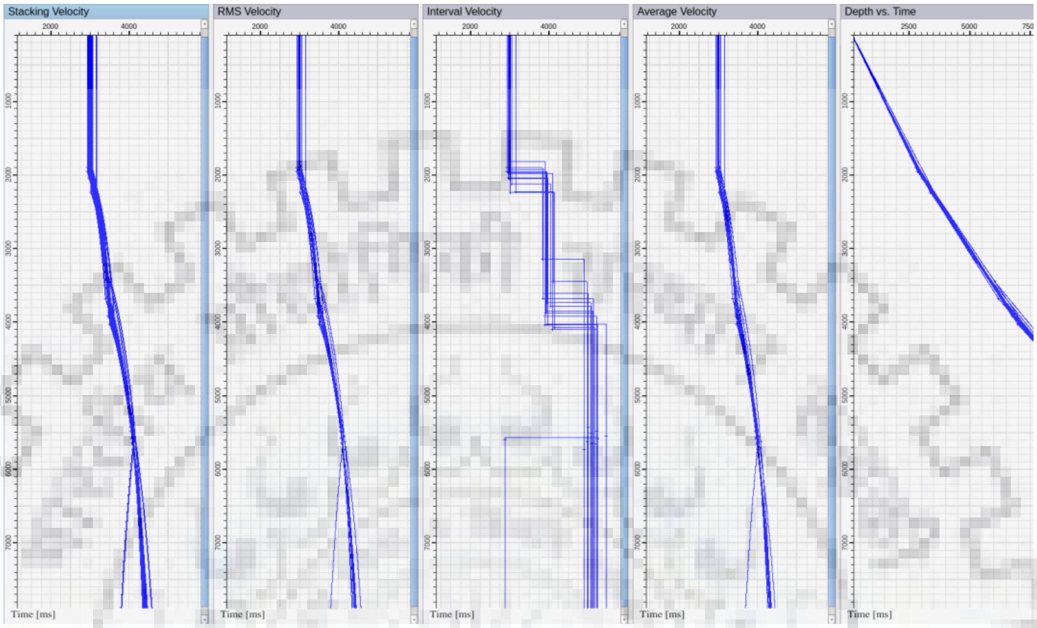


Figure- 4.29- Vertical Function window after loading velocity function

As can be seen from Fig-4.29, the trend for picking velocity is kept to get a uniform vertical section.

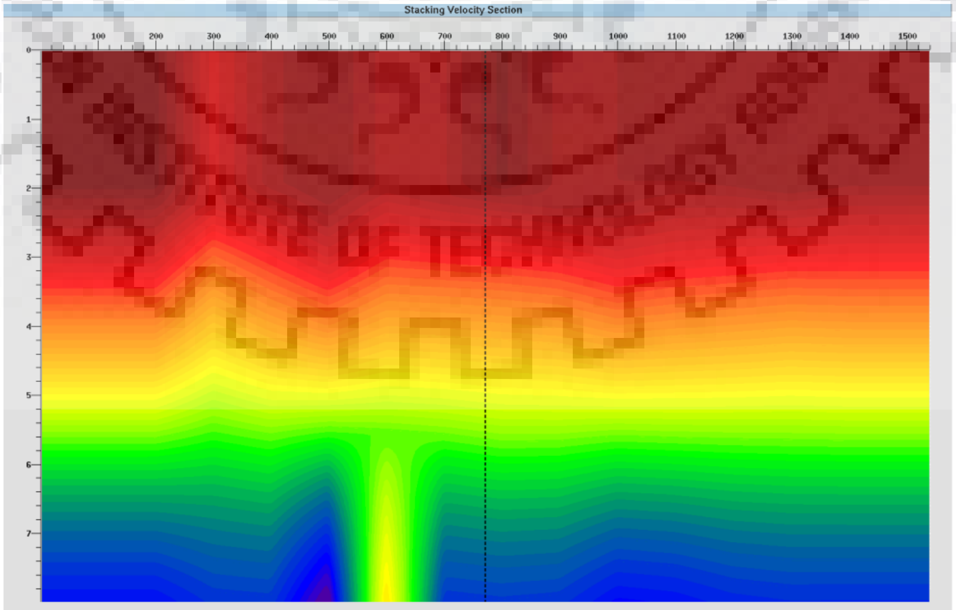


Figure-4.30- Stacking velocity section for the picked velocities

Velocity section shows a comprehensive picture of how the velocity function varies with offset (Fig. 4.30). With the help of velocity function, brute stack can be created.

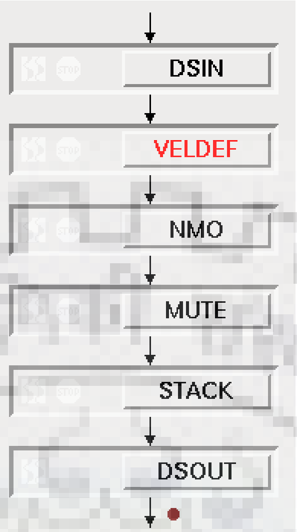


Figure-4.31-Processing flow to create brute stack

Velocity function already generated is used to create with the help of modules like NMO and STACK given in Fig-4.31.

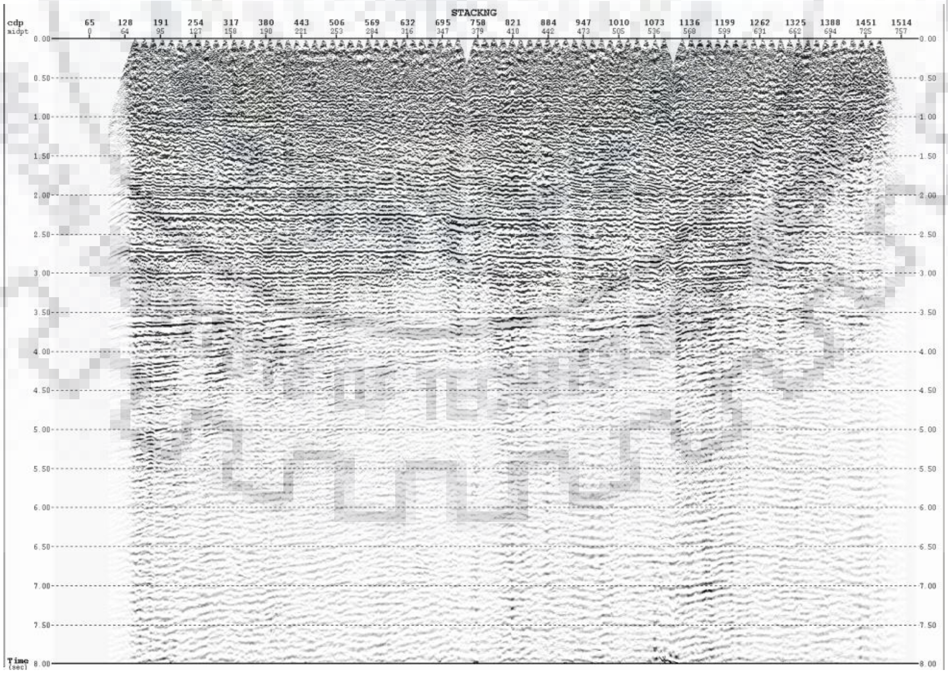


Figure-4.32- Brute stack

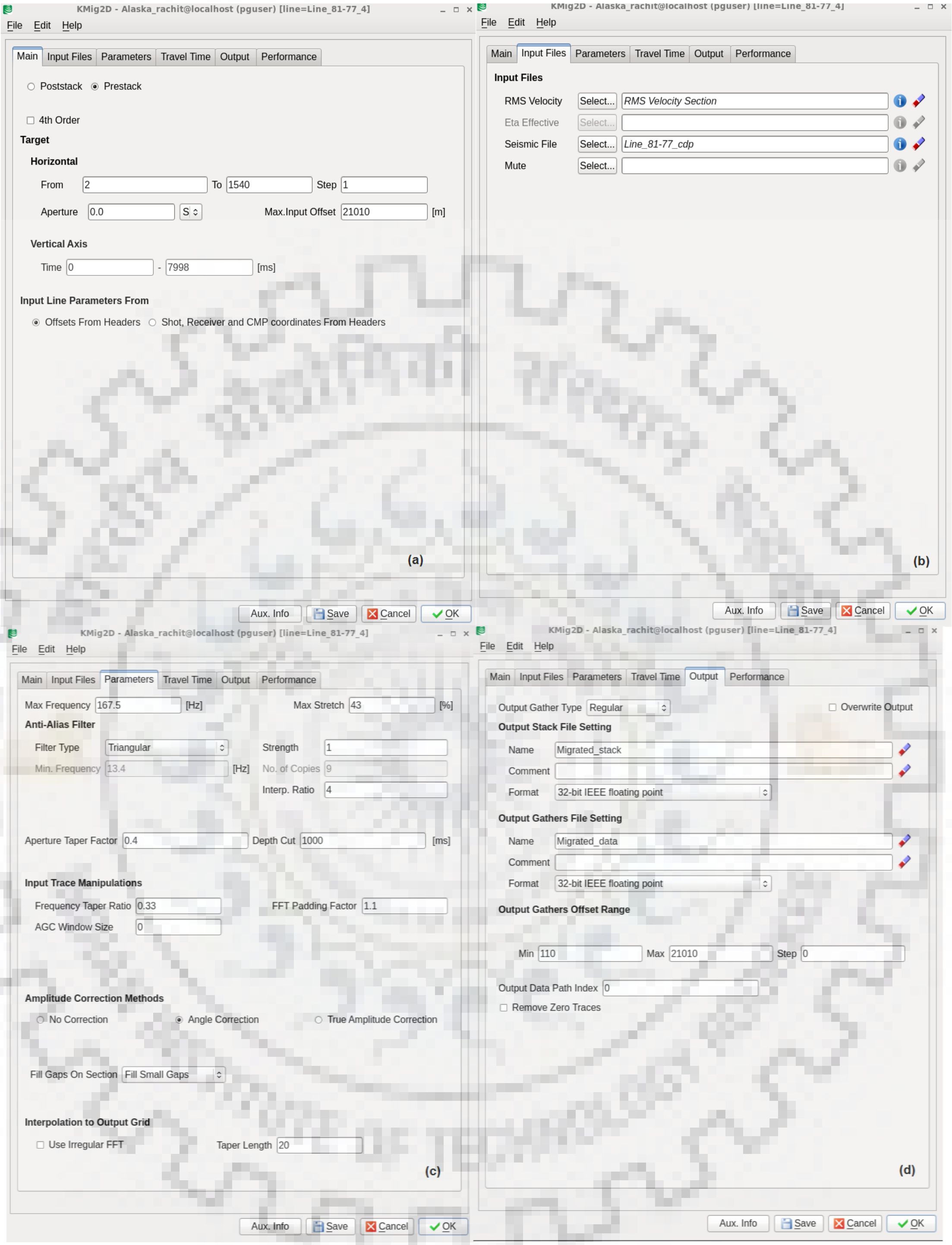
Brute stack, in Fig-4.32, is very important to obtain as it gives an idea as to how the section might look like after migration. Moreover, it helps in improving velocity function.

4.2 Migration

After removal of noises and carrying out deconvolution and CDP stacking, Migration is the next step to be carried out. Migration, in Paradigm, is done with the help of GEODEPTH program where many methods of migration can be carried out. Out of many options, 2-D Fast Prestack Kirchhoff Migration is carried out. For migration, RMS velocity is required which is obtained from Stacking velocity by using Velocity Navigator in Paradigm window.

The Kirchhoff migration is the most commonly used migration for time processing. It is particularly attractive due to its speed and target-oriented capability, which enables efficient velocity model building and updating. In addition, the Kirchhoff migration offers adaptability to irregular acquisition geometries.

After feeding all the input files and parameters to the system (Fig. 4.33), Migration process is carried out by system.



(a) Main

○ Poststack ● Prestack

☐ 4th Order

Target

Horizontal

From 2 To 1540 Step 1

Aperture 0.0 S Max.Input Offset 21010 [m]

Vertical Axis

Time 0 - 7998 [ms]

Input Line Parameters From

● Offsets From Headers ○ Shot, Receiver and CMP coordinates From Headers

(b) Input Files

Input Files

RMS Velocity Select... *RMS Velocity Section*

Eta Effective Select...

Seismic File Select... *Line_81-77_cdp*

Mute Select...

(c) Parameters

Max Frequency 167.5 [Hz] Max Stretch 43 [%]

Anti-Alias Filter

Filter Type Triangular Strength 1

Min. Frequency 13.4 [Hz] No. of Copies 9

Interp. Ratio 4

Aperture Taper Factor 0.4 Depth Cut 1000 [ms]

Input Trace Manipulations

Frequency Taper Ratio 0.33 FFT Padding Factor 1.1

AGC Window Size 0

Amplitude Correction Methods

○ No Correction ● Angle Correction ○ True Amplitude Correction

Fill Gaps On Section Fill Small Gaps

Interpolation to Output Grid

☐ Use Irregular FFT Taper Length 20

(d) Output

Output Gather Type Regular ☐ Overwrite Output

Output Stack File Setting

Name Migrated_stack

Comment

Format 32-bit IEEE floating point

Output Gathers File Setting

Name Migrated_data

Comment

Format 32-bit IEEE floating point

Output Gathers Offset Range

Min 110 Max 21010 Step 0

Output Data Path Index 0

☐ Remove Zero Traces

Figure-4.33- Window for Migration containing (a) “Main” tab for input (b) “Input File” tab for file to be provided for migration including seismic trace and RMS velocity (c) “Parameter” tab for parameter input (d) “Output” tab for labeling output files

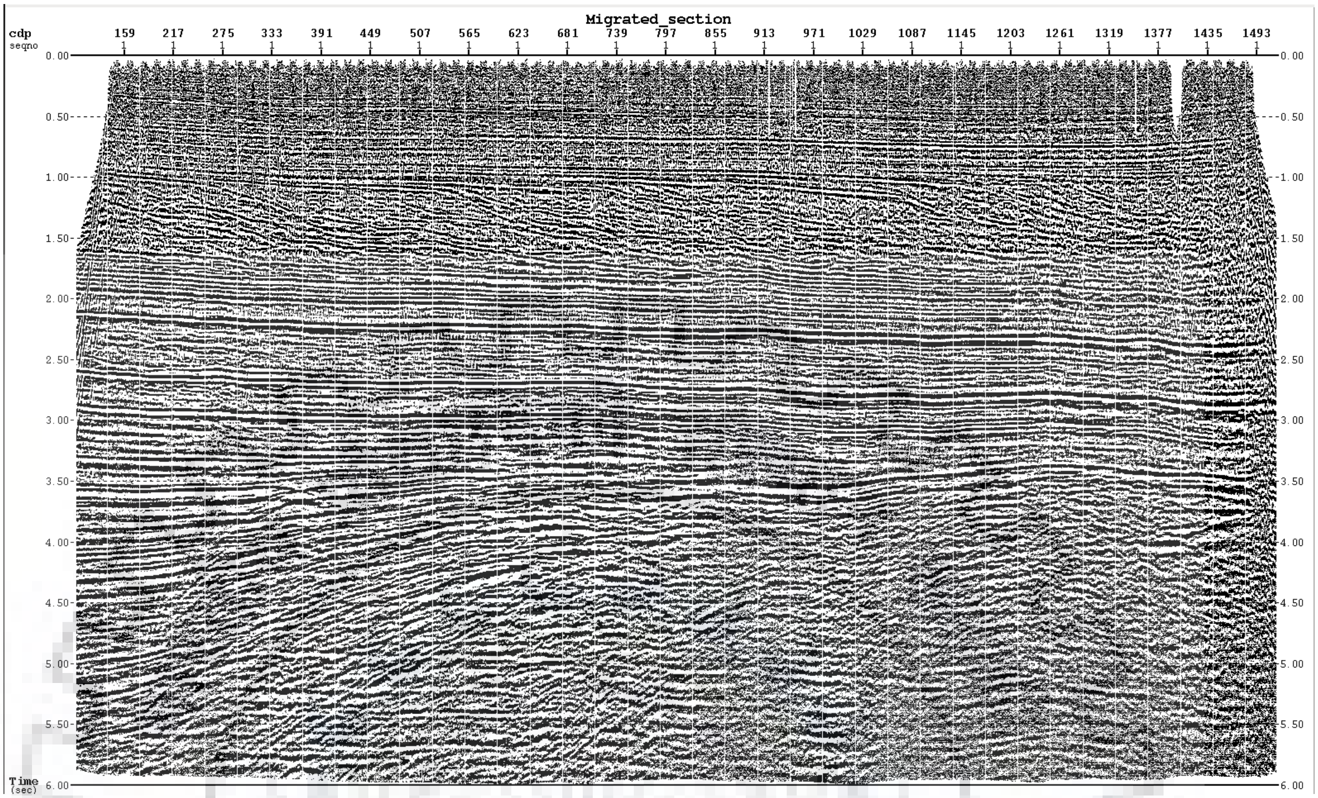
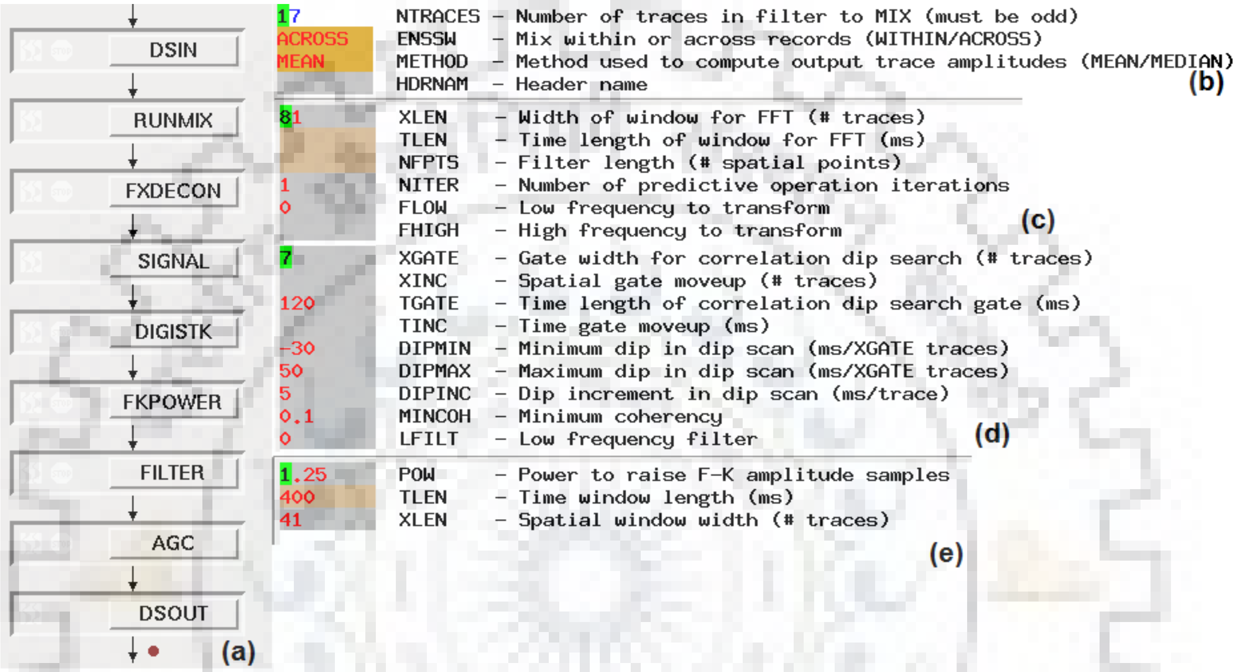


Figure-4.34- Migrated Section

4.2.1 Post -processing

Even after obtaining the migrated section, a few touch-ups are required (Fig. 4.35) to be used so that the section appears better and clearer.



```
17        NTRACES - Number of traces in filter to MIX (must be odd)
ACROSS    ENSSW   - Mix within or across records (WITHIN/ACROSS)
MEAN      METHOD  - Method used to compute output trace amplitudes (MEAN/MEDIAN)
          HDRNAM  - Header name

81        XLEN    - Width of window for FFT (# traces)
          TLEN    - Time length of window for FFT (ms)
          NFPTS   - Filter length (# spatial points)
1         NITER   - Number of predictive operation iterations
0         FLOW    - Low frequency to transform
          FHIGH   - High frequency to transform

7         XGATE   - Gate width for correlation dip search (# traces)
          XINC    - Spatial gate moveup (# traces)
120       TGATE   - Time length of correlation dip search gate (ms)
          TINC    - Time gate moveup (ms)
-30       DIPMIN  - Minimum dip in dip scan (ms/XGATE traces)
50        DIPMAX  - Maximum dip in dip scan (ms/XGATE traces)
5         DIPINC  - Dip increment in dip scan (ms/trace)
0.1       MINCOH  - Minimum coherency
0         LFILT   - Low frequency filter

1.25      POW     - Power to raise F-K amplitude samples
400       TLEN    - Time window length (ms)
41        XLEN    - Spatial window width (# traces)
```

Figure-4.35 (a) Processing flow for Post-processing job (b) Parameters used for RUNMIX module (c) Parameters used for FXDECON module (d) Parameters used for SIGNAL module (e) Parameters used for FKPOWER module

RUNMIX, in fig-4.35 (b), performs a running mix of seismic traces and outputs the mixed traces for further processing. Data input to the program may be stacked or unstacked and sorted in any order. The number of consecutive input traces used to calculate each mixed trace is determined by the user-supplied value for parameter NTRACES which in this case is 17. The mixed trace is output in the place of the center trace in the NTRACES group. RUNMIX then moves one trace and repeats the process. There are two methods for calculating the mixed output traces. They are the MEAN method and the MEDIAN method.

FXDECON, in Fig-4.35 (c), enhances signals. The program uses a fast Fourier Transform to transform a specified number of traces into the f-x frequency domain. Each frequency in a user-specified range of frequencies is then analyzed independently for signal, using a deconvolution-type algorithm.

SIGNAL, in Fig-4.35 (d), is a prerequisite to the DIGISTK program, which is a signal enhancement process. Both SIGNAL and DIGISTK should ordinarily be run toward the end of the processing sequence. Seismic data input to SIGNAL may be prestack gathers or single fold stacked traces. SIGNAL estimates those coherent components of the input seismic data that are aligned linearly over XGATE traces, and which have a total dip within the range of DIPMIN to DIPMAX milliseconds. The resultant estimated “signal” traces are alternated with the original data traces on output, causing the number of output traces to be double the number of input. DIGISTK combines original data traces and signal traces output by the SIGNAL program.

The function of FKPOWER, in Fig-4.35 (e), is to enhance the signal in a window of seismic data. The program performs a multichannel, time-variant operation as follows:

- A window of data is transformed into the F-K domain.
- The amplitude of each F-K sample is modified by raising it to a user-specified power. The phase of the FK-domain samples is not changed.
- An inverse transform back to the time-space domain is performed on the data.
- The window is advanced by 50% of the time length, and the process repeats for the new window. The output is linearly tapered between window centers.

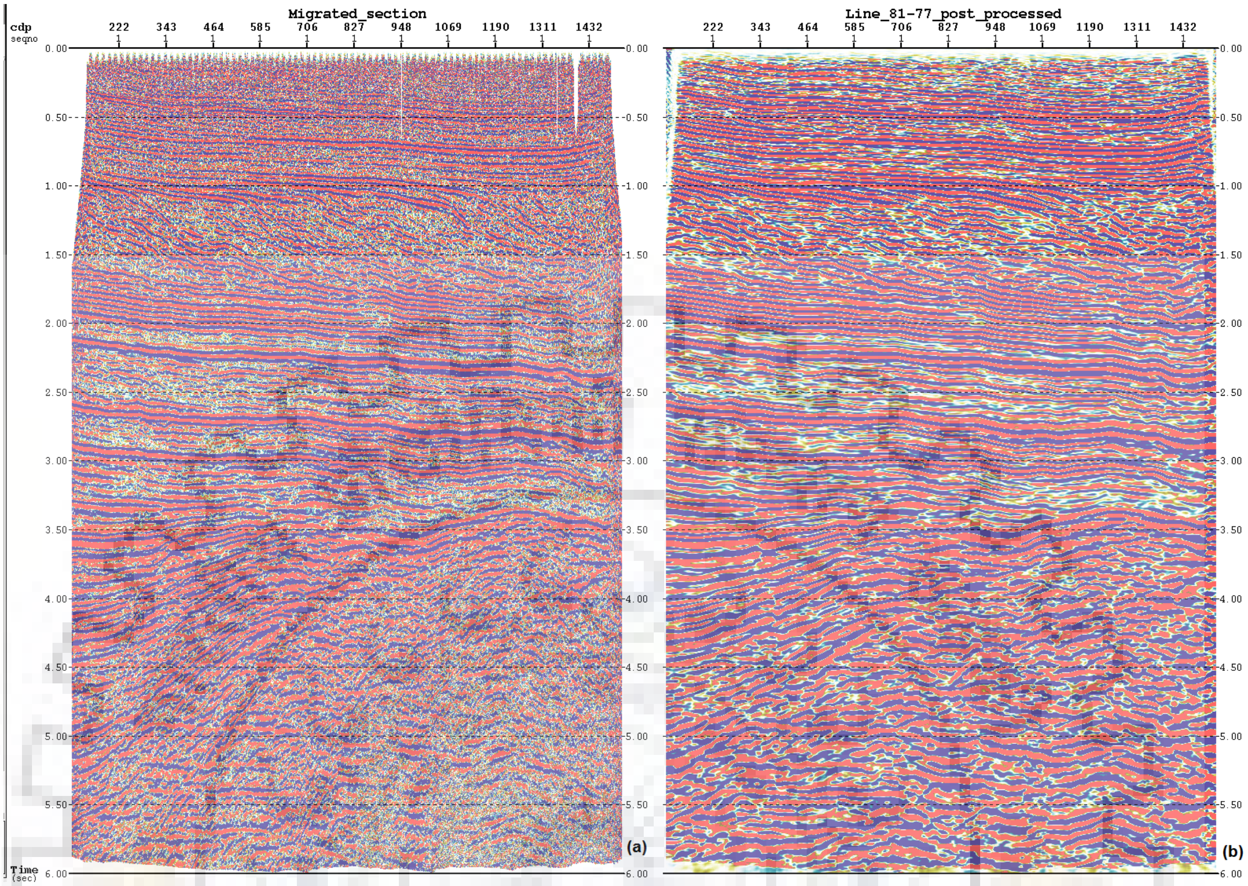


Figure-4.36 (a) Migrated section as input for Post processing job (b) Output section after Post processing

As a result of post-processing, the reflections and horizons are enhanced as compared to the migrated section (Fig. 4.36).

Chapter 5: Results

A comprehensive study is carried out for migrated section of all the lines. A critical aspect of this study was the ability to identify horizons in the seismic reflection profiles that could be correlated to the geology discussed in Chapter-2. The main aim to carry out these processes is to find different geological structures (if observed) and ultimately to find if there are some prospects of oil and gas in the region as Alaska is said to have a lot of reserve of oil and gas. Neighboring areas of Umiat basin have some oil field like Prudhoe Bay Oil Field or prospects of oil and gas making this basin an interesting area to work on.

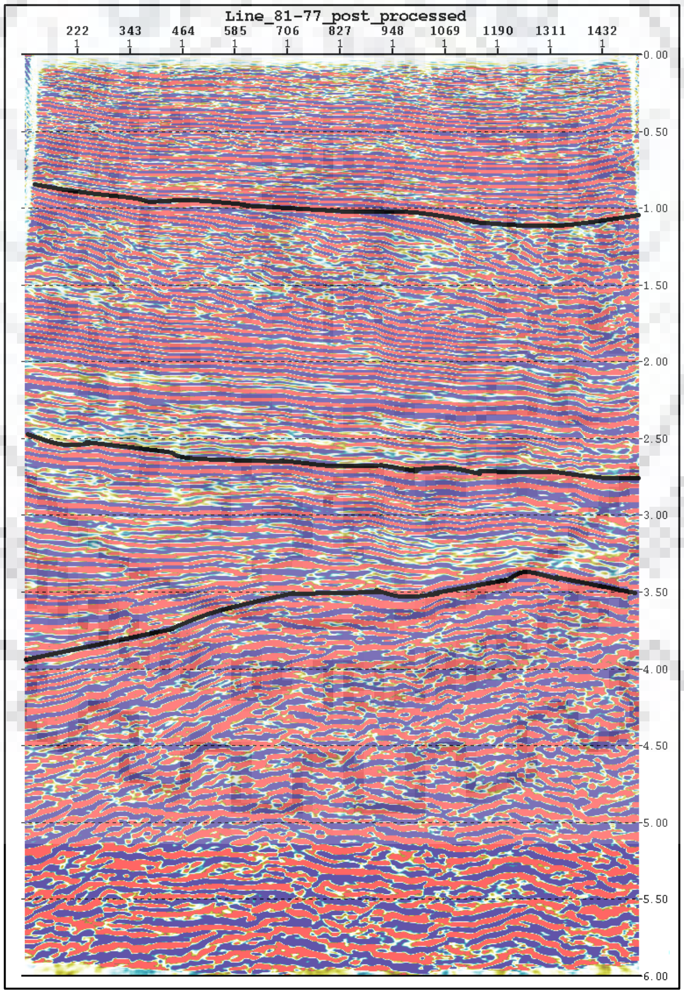


Figure-5.1- Final Migrated section for line 81-77 (black lines are marked horizons)

For all the five sections, major horizons are marked with black line (Fig. 5.1). Time horizons were chosen as either unconformity (evidenced by upper boundary onlapping and lower boundary truncation), depositional hiatuses (upper boundary concordance and lower boundary truncation or onlap), or maximum flooding surfaces (basin wide transgressive sequence with lower boundary onlap and upper boundary concordance).

The last horizon can be considered to be the start of the basement as the reflection below that horizon is not clearly visible and hence are difficult to interpret. This is true for all the lines which can be observed in Figs. 5.1, 5.2, 5.3, 5.4, and 5.5. For all of the five profiles, the basements starts at the same depth establishing that it is in fact the complex basement discussed in chapter-2.

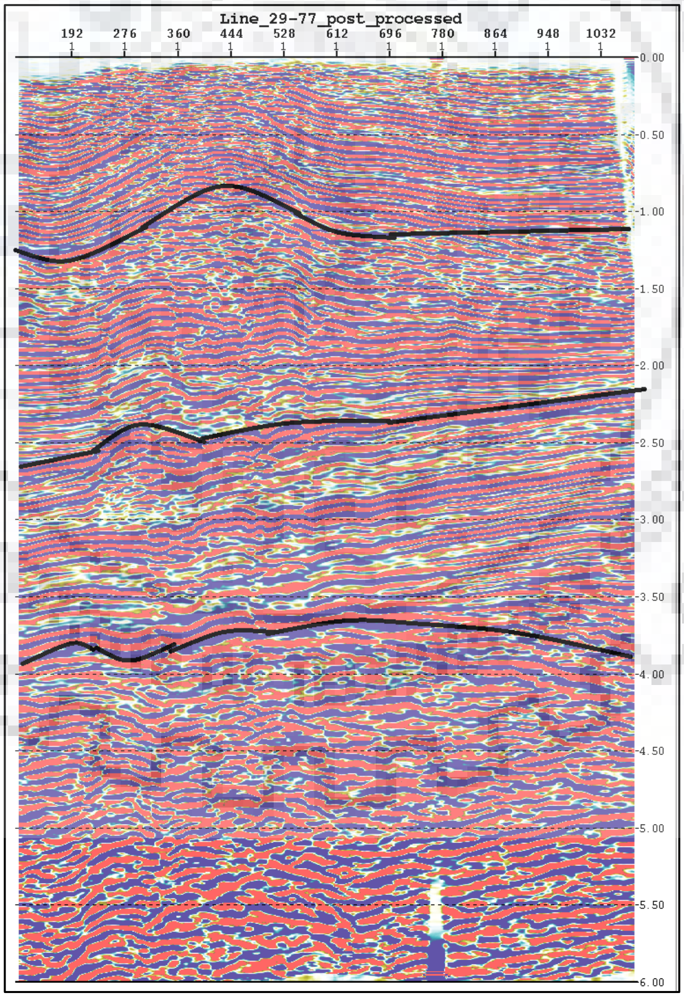


Figure-5.2- Final Migrated section for line 29-77 (black lines are marked horizons)

In Fig-5.2, an anticline fold can be observed at first horizon and that lithology is continued above that horizon. This lithology is a suitable location for traps for oil and gas after the migration of oil happens.

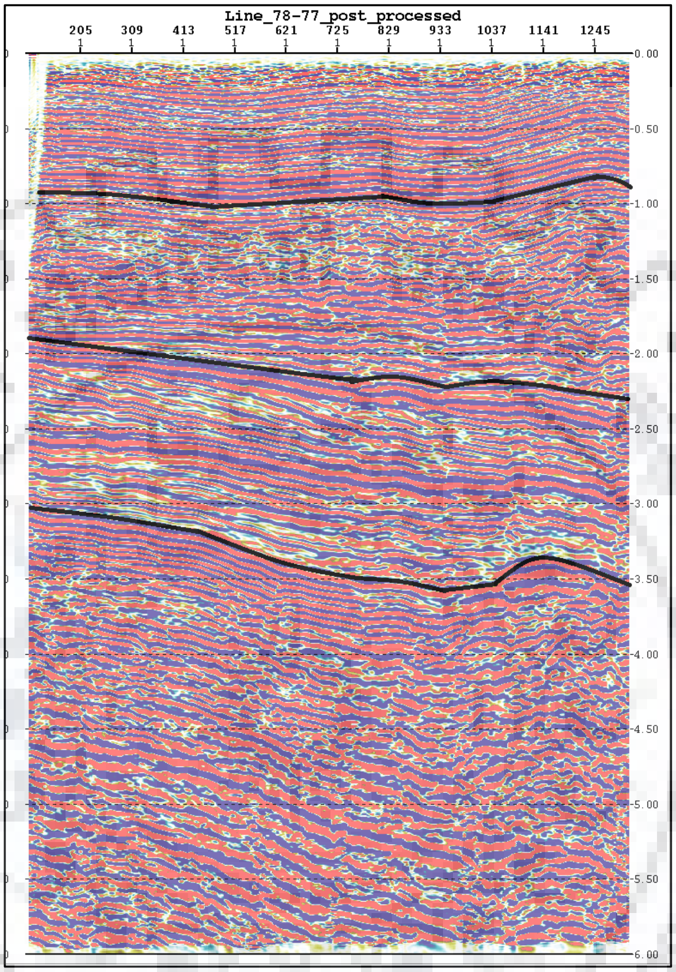


Figure-5.3- Final Migrated section for line 78-77 (black lines are marked horizons)

In Fig-5.3, a downward trend after the second horizon can be observed which is not present before that horizon. It may have been due to the orogeny of the region tilting the basement first and as a result, subsequent deposition is also tilted. Though, there may be other reasons to the following feature as well.

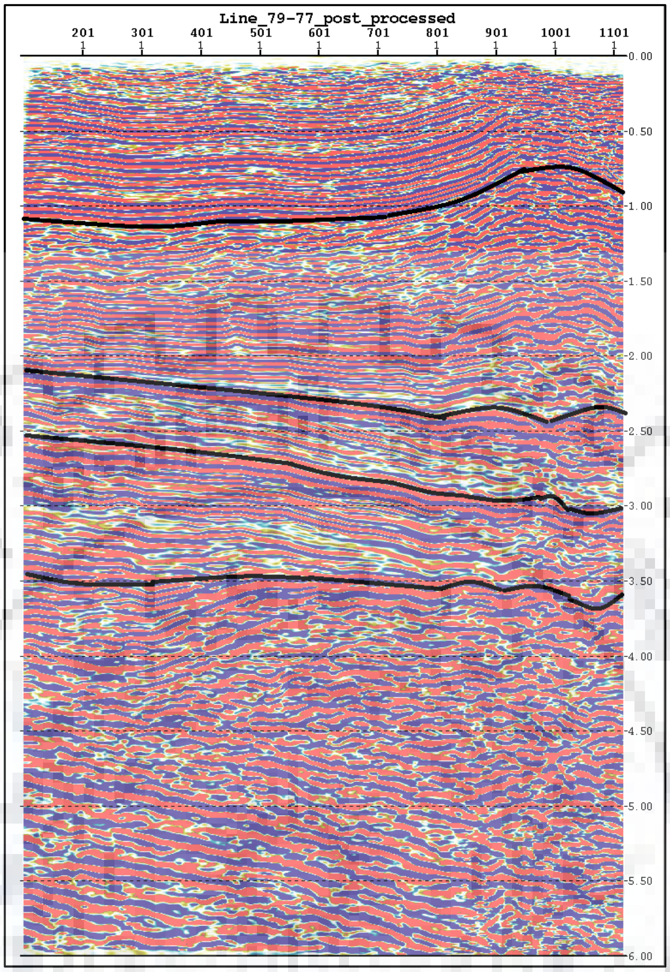


Figure-5.4- Final Migrated section for line 79-77 (black lines are marked horizons)

In Fig-5.4, another anticline is observed but as can be analyzed from Fig-3.1 both the lines, that is, line-29-77 and line 79-77 are adjacent to each other. Thus, it can be possible that both these anticlines are, indeed, the same anticline recorded by different lines from different position.

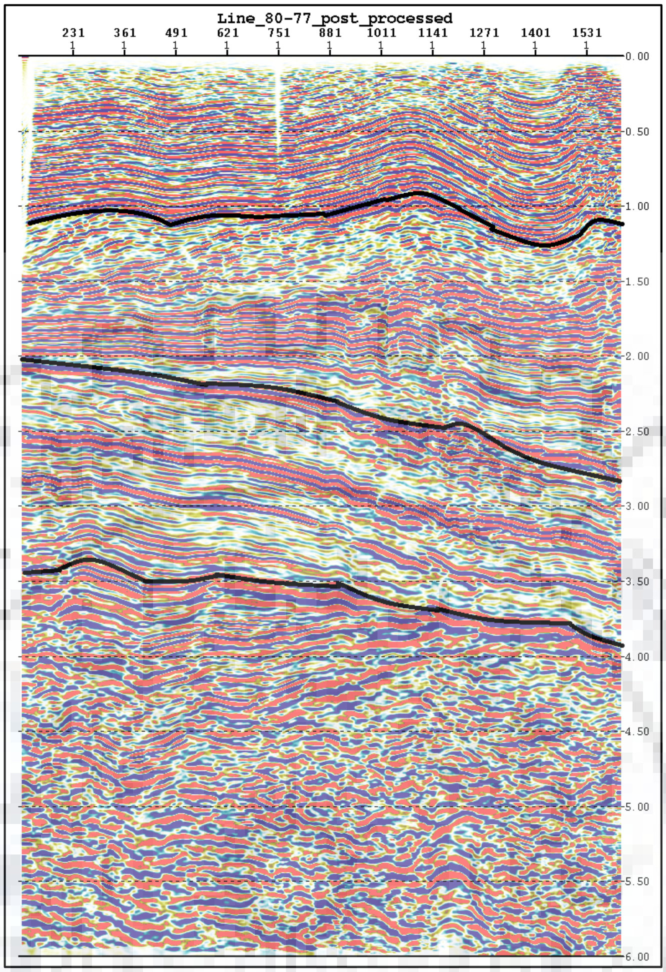


Figure-5.5- Final Migrated section for line 80-77 (black lines are marked horizons)

The same anticline can be observed in Fig-5.5 which can be seen in Fig-5.2 and Fig-5.4. Moreover, the dipping horizon can also be seen in Fig-5.5. This shows a continuity of horizons in all of the five profiles and can be studied further for sediment deposition and orogeny study.

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