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Processing Seismic Data with Open Source Software

Ali M. Al-Rahim, Laith F. Terky

University of Baghdad, Department of Geology, Baghdad, Iraq.

Abstract**—**open source seismic processing softwares provides a low cost alternative to commercial softwares and, with an appropriately directed development, an ability to adapt to the changing research needs. The best known example of such kind is Seismic Unix, a free reflection processing system developed at the Colorado School of Mines. It has been broadly used in research and teaching seismology and also in smaller scale seismic processing industry. Through this paper the seismic Unix was tested for the first time at Iraqi academic system by processing a real seismic data acquired at northern Iraq at Basra province. The test done by reliance a simple processing flow and the result show us high resolution seismic section and less noise ratio. According to the early mentioned results the seismic Unix recommended as a teaching tool for Iraqi educational system.

Keywords— Processing Seismic Data, Open Source Software, Basra province.

I. INTRODUCTION

Analysis of geophysical data nearly always involves application of sophisticated and multi-stage processing and inversion. With volumes of data and resolution of the datasets exploding in the recent years in nearly every field, the demand for computer packages facilitating, handling, processing, analysis, and interpretation of large and complex datasets is growing especially in exploration seismology [1].

Although highly advanced, commercial processing packages are still built for specialized industry users. For a broader geophysical community, reliance on such software may not be satisfactory because commercial packages often require installation of other systems (e.g., databases or rendering systems) whose support could be difficult or expensive in a university environment. And licensing costs are often prohibitive, particularly when utilizing large multi-processor computer systems [1].

Open-source seismic processing softwares provides a low-cost alternative to commercial software, with an appropriately directed development, and an ability to adapt to the changing research needs. There are many open- source seismic processing software which developed through of academics like Seismic Unix, researcher like Madagascar, universities like SEP lib and companies like Free USP.

In this paper the focus will be on open-source seismic processing software ability in processing of real seismic data set. In order to evaluate the efficiency of open-source seismic processing software Seismic Unix was chosen to process real seismic data provided by local contractor and according to the deal with the contractor the original coordination of the data set will be obscure.The end result of this paper is the qualification of open-source seismic processing software which is represented by seismic Unix to be used inseismic processing with more flexibility and relevance to the requirement of scientific research.

II. THE SEISMIC DATA

As mention earlier that the coordinate of the data will be obscure because of the project didn't end yet. The data was acquired in south of Iraq in an area located in Basra province as in *Fig.1*.According to the survey report the seismic data was formed from 164 shot between two shots 100m shot interval. the survey layout type is split spread each record have one shot (source point) and 96 receiver (geophone) distributed evenly 48 receiver on each side of the shot between two receivers 50m receiver interval.

Fig.1: Basra province location.

III. SEISMIC PROCESSING SEQUENCE

Seismic data processing techniques are designed to discriminate, separate, or otherwise attenuate the noise and enhance the signal. Seismic data processing converts

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the acquired seismic signals to a representation of the subsurface geology [2] as in *Fig 2*.

The processing sequence in *Fig.2* represent the conventional processing sequence. In this paper the processing sequence will be depend on special test to detect the filters parameter and the trial and error this will led us to different processing sequence which improve signal to noise ratio and maximize the resolution of the subsurface section.

IV. SEISMIC DATA PROCESSING

4.1 Data Conversion.

The data format changed from seg-y to su (seismic Unix format) in order to be read by seismic Unix. The conversion done when the data trace header can be read by seismic Unix. The trace header information represent the first and primitive defined (in seismic Unix) information of the data as in Table.1.

(1) Preprocessing:
- **Demultiplexing**
- **Reformatting**
- **Editing**
- **Geometric Spreading Correction**
- **Setup of Field Geometry**
- **Application of Field Statics**

(2) Deconvolution and Trace Balancing

(3) CMP Sorting

(4) Velocity Analysis

(5) Residual Statics Corrections

(6) Velocity Analysis

(7) NMO Correction

(8) DMO Correction

(9) Inverse NMO Correction

(10) Velocity Analysis

(11) NMO Correction, Muting and Stacking

(12) Deconvolution

(13) Time-Variant Spectral Whitening

(14) Time-Variant Filtering

(15) Migration

(16) Gain Application

Fig.2: Seismic Processing sequence[9].

Table.1: The trace header before geometry setup.

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

At this status the trace header not have the advance geometry information like (source and receiver coordinate, common depth point) which is used to velocity analysis.

4.2 Viewing and editing the data.

The seismic data should be cheeked to identify the missing shots, bad shots and noisy and variable traces length if they are available. The data set contain many bad shots as in *Fig.3* which are rejected from the data. After rejection the bad shots the trace and shots number will be reduce. The numbering sequence also differ so the data should be reset.All the data set will be shifted after the rejection the shot number 16 will be 15 when the shot 15 reject and so on. The data will be continuous without missing the traces length are equalized also.

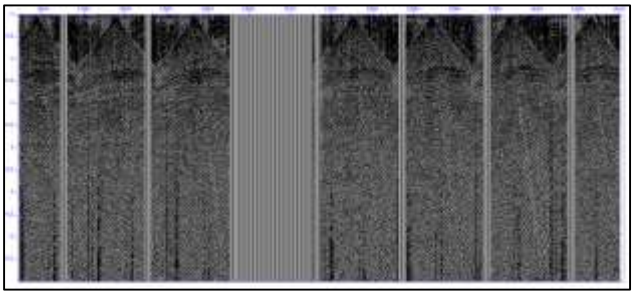

Fig.3: Missing shot in data set.

4.3 Geometry setting.

At this stage the geometry of the data suffer from many losses because of early processing like rejection as in *Fig.4*and the limited traces header information. The normal move out correction and velocity analysis need the data to be sorted in the common depth point domain (cdp) and offset domain. In order to calculate these domains need to shots (sx,sy) and geophones (gx,gy) position. According to the early knowledge about the

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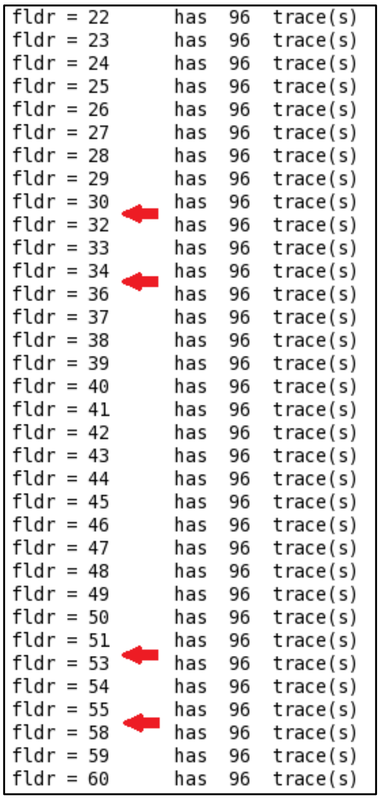
survey area the dip of it gentle dip which have minimum effect on data so the (sy,gy) will be neglected. As result (sx,gx) will be defined in relative way by projection them on imagery x-axes of cartesian coordinate system.



```
fldr = 22    has  96  trace(s)
fldr = 23    has  96  trace(s)
fldr = 24    has  96  trace(s)
fldr = 25    has  96  trace(s)
fldr = 26    has  96  trace(s)
fldr = 27    has  96  trace(s)
fldr = 28    has  96  trace(s)
fldr = 29    has  96  trace(s)
fldr = 30    has  96  trace(s)
fldr = 32    has  96  trace(s)
fldr = 33    has  96  trace(s)
fldr = 34    has  96  trace(s)
fldr = 36    has  96  trace(s)
fldr = 37    has  96  trace(s)
fldr = 38    has  96  trace(s)
fldr = 39    has  96  trace(s)
fldr = 40    has  96  trace(s)
fldr = 41    has  96  trace(s)
fldr = 42    has  96  trace(s)
fldr = 43    has  96  trace(s)
fldr = 44    has  96  trace(s)
fldr = 45    has  96  trace(s)
fldr = 46    has  96  trace(s)
fldr = 47    has  96  trace(s)
fldr = 48    has  96  trace(s)
fldr = 49    has  96  trace(s)
fldr = 50    has  96  trace(s)
fldr = 51    has  96  trace(s)
fldr = 53    has  96  trace(s)
fldr = 54    has  96  trace(s)
fldr = 55    has  96  trace(s)
fldr = 58    has  96  trace(s)
fldr = 59    has  96  trace(s)
fldr = 60    has  96  trace(s)
```

Fig.4: disordered geometry result of reject bad shots.

The geometry of the data wrote in the traces header as a result the new trace headers formed as in *Table.2*

Table.2: Reset trace headers geometry.

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

4.4 Amplitude recovery.

The amplitude recovery is adjusted to seismic data to compensate for attenuation, spherical divergence and other effects. The goal is to get the data to a state where the reflection amplitudes relate directly to the change in rock properties giving rise to them[3].The most important energy losses are due to geometrical spreading, absorption of the rocks and transmission losses. Geometrical spreading is spreading of the wavefront since the energy of a wave is inversely proportional to $1/r^2$ (in a homogeneous medium).Two gain function are applied exponential and time power gain many combination of them tested until get the appropriate one as in *Fig.5*. In order to calibrate the amplitude recovery of the data and because the huge size of the detail in the data set it is better to view the processing results on one seismic shot or in the shot domain.

4.5 Frequency Filter.

Frequency Filter Permit filtering in accord with arbitrarily chosen characteristics that might prove difficult or impossible to achieve with physical circuit components [4]. Digital filter takes the form of an arithmetical operation carried out on the string of numbers that represents the signal [5].

The seismic data suffer from noise which is any disturbance on the seismic record that tends to obscure primary reflections from rock strata. It may be conveniently divided into two sorts random noise and coherent [5]. The noise can be eliminated by filtering. After test many frequency values set for the bandpass filter we find the satisfying as in Fig.6. while other frequency values which are tested ware not satisfying because of over filtering weaken the reflectors, bad noise eliminating and sometime create artifact when the tapering amount not suitable

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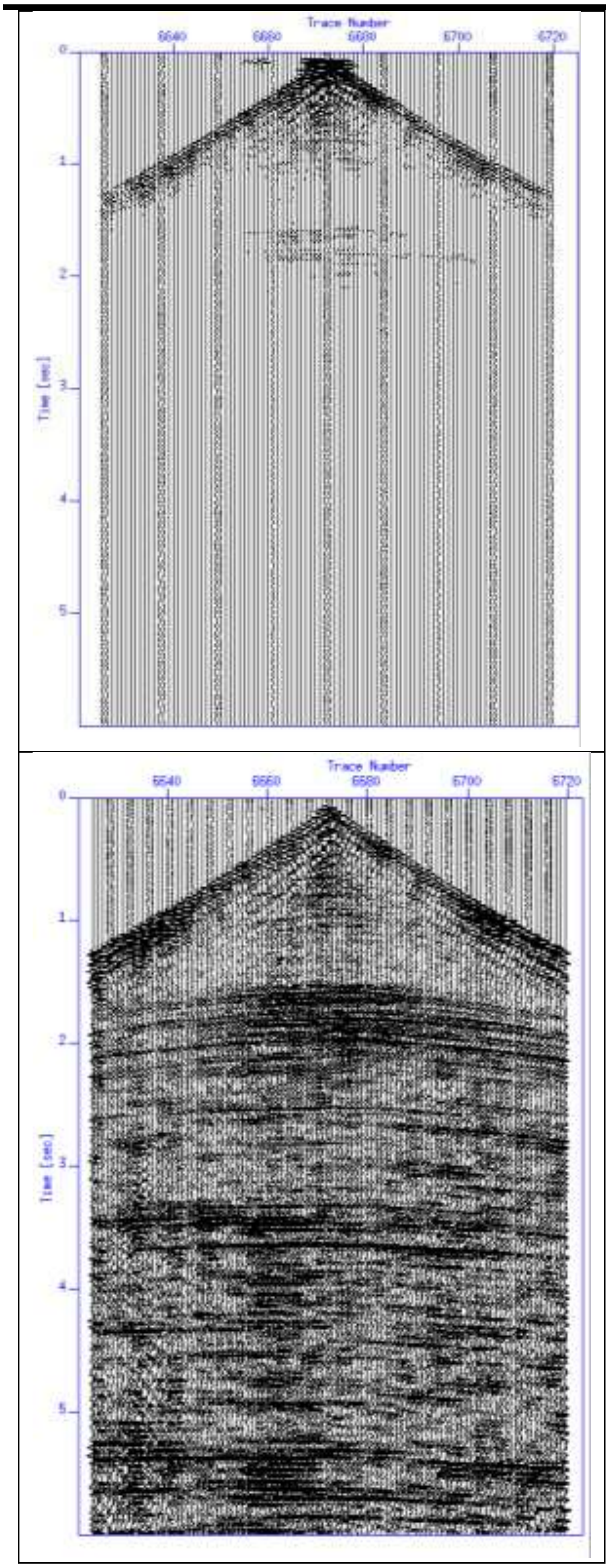

Fig .5: Amplitude recovery of seismic shot upper before gain lower after gain.

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4.6 Velocity filter (Dip filter).

An F–K filteris designed to suppress unwanted events in the frequency-wavenumber (F–K) domain. When applying multidimensional Fourier transforms, such as from (t, x) to (f,k_x), linear events in the original domain will also be linear events in the transformed domain, except that the orientations of each event in the two domains are perpendicular to each other[6].

If there are linear noises, or if there are noises with dip (offset or time) less than a certain angle, such as ground rolls, we can mute such noise in the F–Kdomain, and then transfer the remaining data back to the t–x domain. Hence F–Kfiltering is also called dip-filteringwhen it is used to remove linear events of certain dip angle [7].The best method of designing dip filter is to create the frequency – wave number spectrum of the data the noise will appear as slopes in F-K domain as in *Fig.7*.

When the seismic data in the T-X domain the noise be hard to detect while in the F-K domain the noise obvious as a slopes which then muted by selecting appropriate window of rejecting the noise. The window or zone of rejection defined by selecting the velocity or slope values as in *Fig.8*.

4.7 Muting.

Muting is the process of excluding parts of the traces that contain only noise or more noise than signal.The far geophone groups are quite distant from the energy source. On the traces from these receivers, refractions may cross and mixed with reflection information from shallow reflectors. However, the nearer traces are not so affected.

When the data are stacked, the far traces are muted (zeroed) down to a time at which reflections are free of refractions. The mute schedule is a set of time, trace pairs that define the end of the muting. Mute changes the relative contribution of the components of the stack as a function of record time. In the early part of the record, the long offset may be muted from the stack because the first arrivals are disturbed by refraction arrivals, or because of the change in their frequency content after applying normal moveout The transition where the long offsets begin to contribute may be either gradual or abrupt [8].

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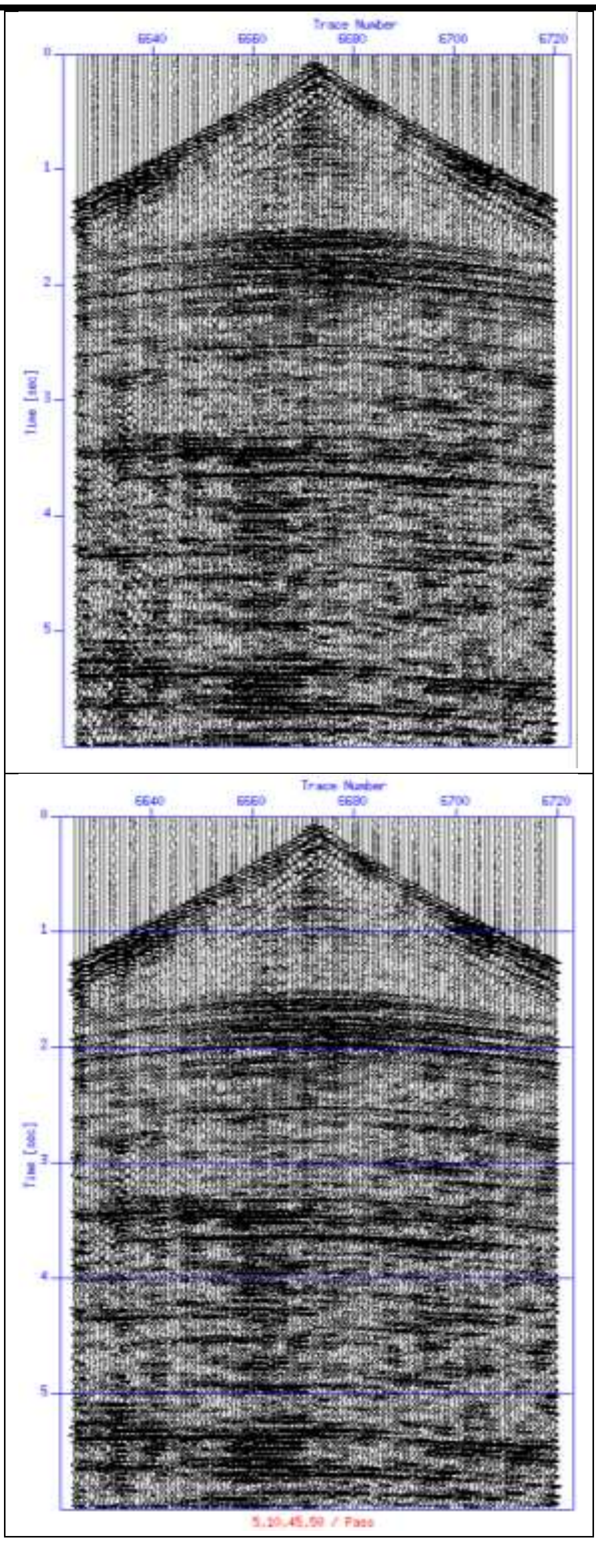

Fig.6: Frequency filter. The upper before filter and the lower after filter.

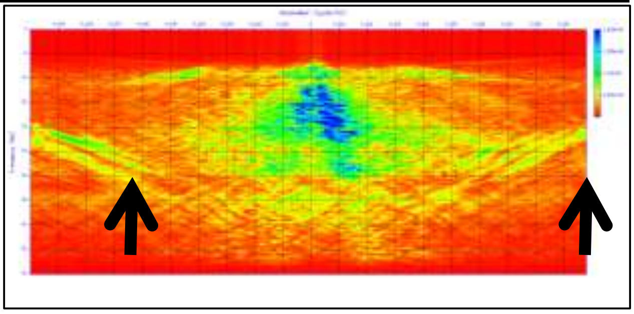

Fig.7: Frequency-wave number domain the noise shaded by the two black arrows they refer to the slopes which represent the noise.

4.8 Deconvloution.

Deconvolution is process designed to enhance the vertical resolution of the seismic data by attenuating the undesirable signals such as short period multiples. It is also called inverse filtering [4]. In order to apply deconvolutionthe autocorrelation function should be applied at first to decide the deconvlution parameters. The autocorrelation is simply the cross-correlation of a signal with itself. The predictive deconvolutionapplied in this paper which is use of information from the earlier part of a seismic trace to predict and deconvolve the latter part of that trace. Some types of systematic noise, such as reverberations and multiplescan be predicted so noise eliminated as in *Fig.8.*

4.9 Sorting.

Seismic data acquisition with multifold coverage is done in shot receiver coordinates. Seismic data processing, on the other hand, conventionally is done in midpoint offset coordinates. The required coordinate transformation is achieved by sorting the data into CMP gathers. Based on the field geometry information, each individual trace is assigned to the midpoint between the shot and receiver locations associated with that trace. Those traces with the same midpoint location are grouped together, making up a CMP gather [9].

4.10 Velocities Picking and Normal moveout correction.

The time correction applied to reflection times because of normal moveout. The normal moveout formed because the difference in reflection arrival time which is result from the geophone is not located at the source point. Usually applied to common-midpoint gathers, it is theadditional traveltime required because of offset,

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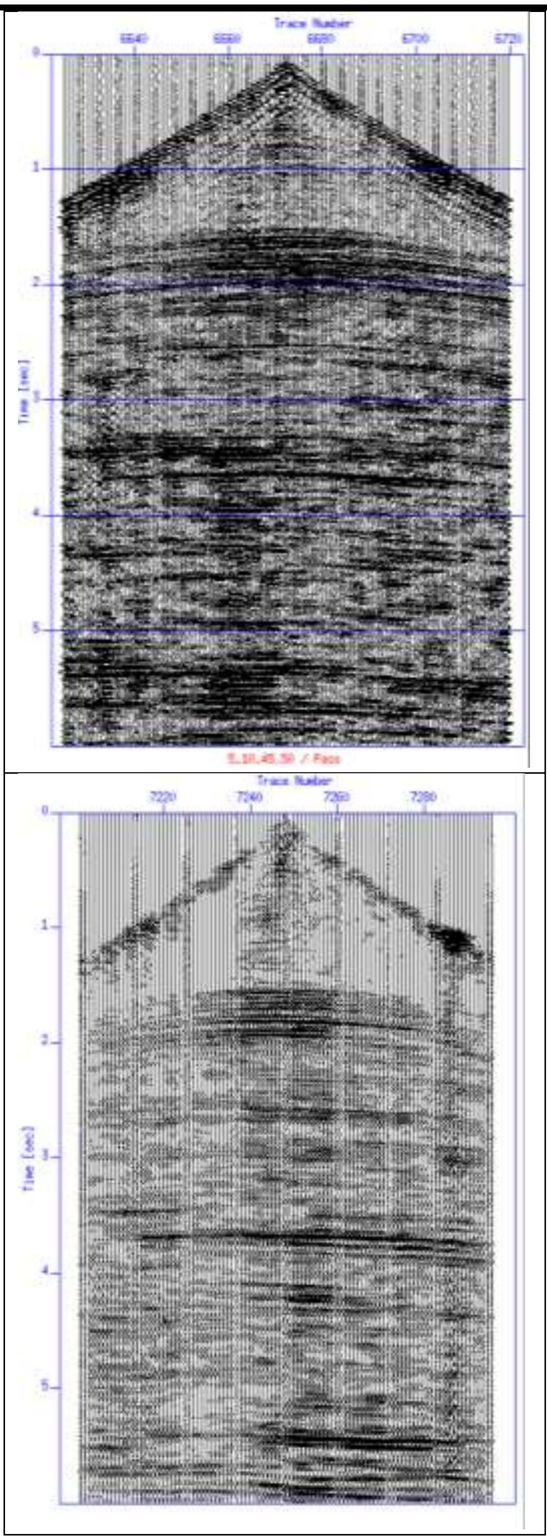

Fig.7: Applying F-K filter to lower section while upper section before filter.

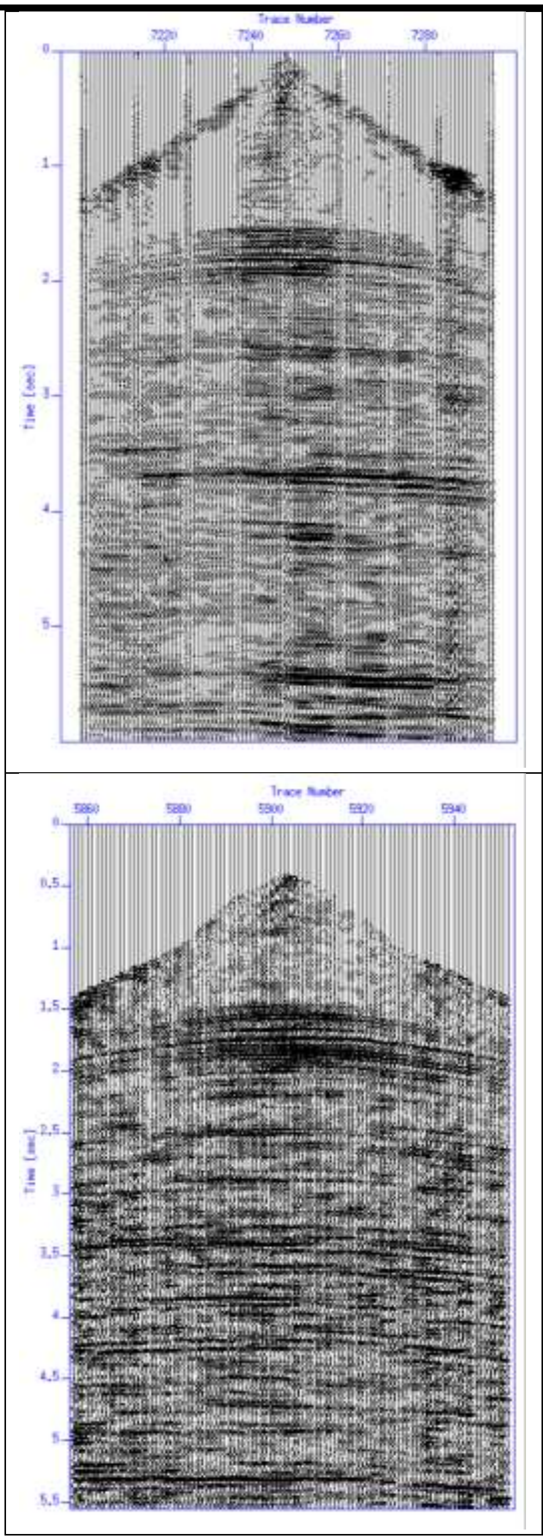

Fig.8: Enhance the vertical resolution after predictive deconvolution in lower section. Upper section before deconvolution.

Assuming that the reflecting bed is not dipping and that raypaths are straight lines. this leads to a hyperbolic as in *Fig.9* shape for a reflection. The normal move out correction done through velocity analysis is the process whereby the velocity that flattens the reflection hyperbola on a CMP/CDP gather is determined. The velocity is called the stacking velocity. In velocity analysis, velocities are picked at selected locations along the seismic section and the results are linearly interpolated from one analysis location to the other as long as the

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picks are from the same reflector and the same reflection time [10] as in *Fig.9.*

4.11 Stacking.

It is a process includes algebraic sum of the all seismic traces fromdifferent shot records with a common reflection point, such as commonmidpoint (CMP) data are stacked to form a single trace during seismicprocessing [11]. For stacking the NMO correction must be applied to theseismograms to get on map of zero offset travel time. Since the traces fromdifferent offsets contain information for a common point of the horizontalreflector, the redundant information can be summed up constructively togenerate a stacked section of higher S/N ratio as in *Fig.10*, since the stack consider bestfilter to attenuate the random noise[12].

V. CONCLUSION

The open source seismic processing software (seismic Unix) was useable in processing real seismic data as seen in the end of the processing in this paper at the stacking where seismic section was high resolution and less noise. Seismic Unix because it is open source and has a wide range of developer which they are researcher so this makes it highly adapted to many uses in seismology, exploration, and engineering seismic and also updated. The seismic Unix not needs license it is a free software this make itfavorite for academic and researcher community. Seismic Unix is open source the permits accesses to its source code this enhance the student knowledge about the seismic processing routines.

The open source softwares like seismic Unix have limitations such as Seismic Unix do not support the user interface, it is built on pipe system call of Unix which cause spending time on writing orders, seismic Unix relatively slow because of pipe system call and seismic Unix not able to process big seismic data in normal circumstances.

These advantages and limitations led as to the possible applications of open source processing softwares such as reliance then as educational courses in colleges, institutes and other scientific organization of Iraq, use them by Iraqi student and researchers for the development of new processing algorithms and tested it and using the open

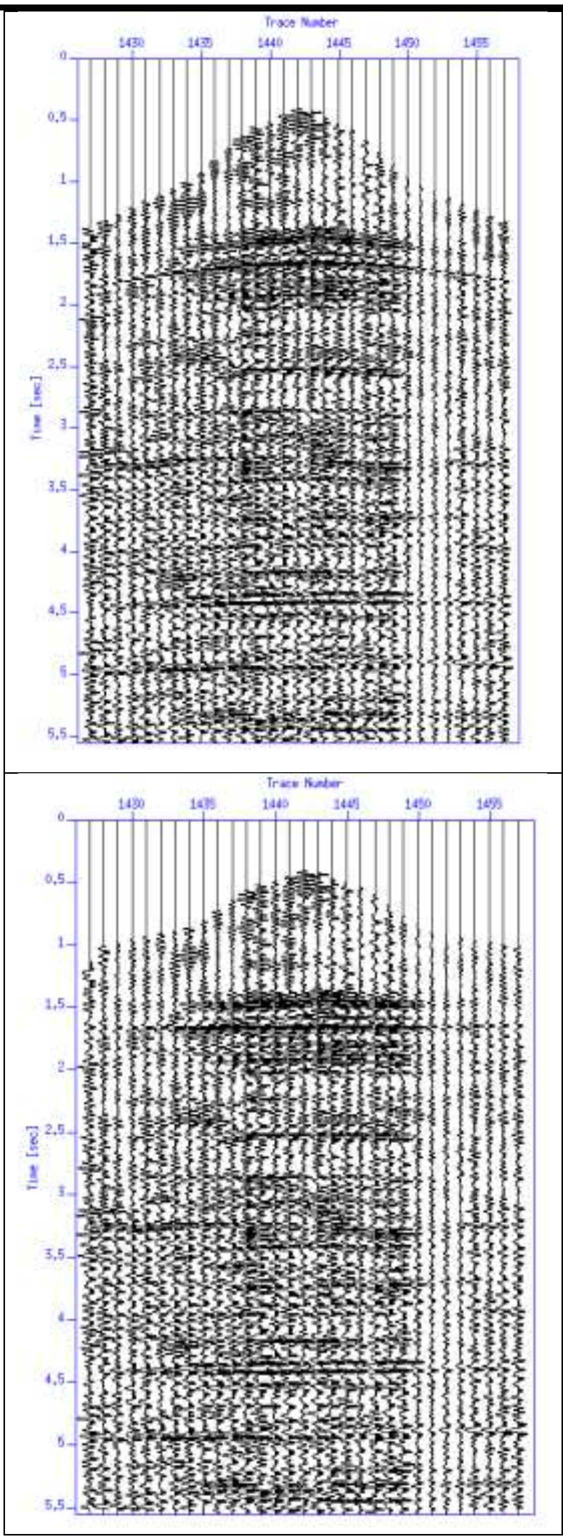

Fig.9: NMO correction in lower section while in the upper section the reflectors look like hyperbola.

Source softeares in Iraqi educational foundations connect the Iraqi academic community with the software's developers community so that enable shearing problems and solutions which led to developing the Iraqi academic community.

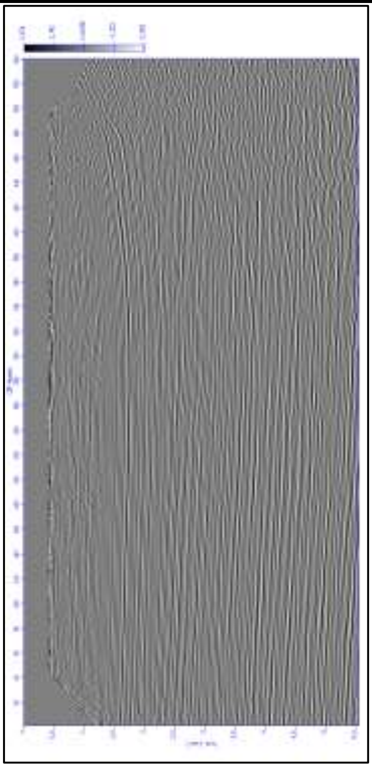

Fig.10: The stack section.

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