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Linear Noise Removal Using Tau-P Transformation on 3D Seismic Data of Al-Samawah Area - South West of Iraq

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Abstract
Tau-P linear noise attenuation filter (TPLNA) was applied on the 3D seismic data of Al-Samawah area south west of Iraq with the aim of attenuating linear noise. TPLNA transforms the data from time domain to tau-p domain in order to increase signal to noise ratio. Applying TPLNA produced very good results considering the 3D data that usually have a large amount of linear noise from different sources and in different azimuths and directions. This processing is very important in later interpretation due to the fact that the signal was covered by different kinds of noise in which the linear noise take a large part.

Keywords: Noise attenuation, Tau-P transformation, 3D seismic processing.

ازالة الضوضاء الخطية بأستخدام تحويل Tau-P على البيانات الزلزالية ثلاثية الأبعاد في منطقة السماوة جنوب غرب العراق

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الخلاصة
تم توهين الضوضاء الخطية على البيانـات الزلزالية ثلاثية الأبعاد في منطقة السماوة جنوب غرب العراق بأستعمال مرشـح (TPLAN) Tau-P الذي يقوم بتحويل البيانات من Time domain الى Tau-P domain لغرض تحسين نسبة الأشارة الى الضوضاء. تطبيق مرشح TPLNA اعطى نتائج جيدة جدا بالأخذ بنظر الأعتبار ان البيانات الزلزالية ثلاثية الأبعاد تحتوي عادة على كميات كبيرة من الضوضاء الخطية التي تكون ناتجة من مصادر واتجاهات مختلفة. هذه العملية تكون مهمة جداً لأغراض التفسير لاحقاً حيث ان الأشارة تكون مغطاة بأنواع مختلفة من الضوضاء والتي تكون نسبة كبيرة منها هي الضوضاء الخطية.

1. Introduction

Geophysical data processing is the use of computers for the analysis of geophysical data [1]. Reflection of the seismic data that is acquired in the field has to be performed through several processing steps before it can be interpreted in terms of the subsurface structure. The source signal, on its way down and back up to the receivers, is affected by many factors [2]. A 3-D acquisition geometry should be designed such that, at the end of the acquisition and the processing sequence, the wanted signal can be reliably interpreted and the noise is suppressed as much as possible [3]. Different types of noise can be found in seismic data, where it is important to suppress the noise for seismic processing and interpretation [4]. Generally, the term "noise" that is used in seismology can be applied to all types of disturbance which may interfere in exploration seismology. Seismic noise is

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divided into two main types; coherent and incoherent (random) noise [5]. Coherent noise is often coexisting with random noise in seismic field data. The attenuation of different kinds of noise plays a key role in data processing to enhance the signal ratio for the data. The coherent noise's characteristics are considerably different than those of random noise. A general approach requires designing filtering techniques based upon the characteristics of noise and applying noise suppression to target each noise type separately [6]. A large group of unwanted energy consists of linear noise, such as ground roll, air waves, head waves, direct waves, guided waves… etc. After noise filtration, all further processing steps become more reliable, especially deconvolution, velocity analysis, migration and stacking. Therefore, proper signal-to-noise ratio improvement is very important [7]. The tau-p transform is a powerful processing tool to preserve uniqueness of the seismic data as it affords an increased separation between different seismic waves [8].

2. Study Area

The city of Samawah is the modern capital of the Al Muthanna Governorate that is located 280 km southeast of Baghdad. The city is located midway between Baghdad and Basra, as shown in Figure-1. The coordinates for the 3D seismic survey are shown in Table-1. The acquisition parameters for the 3D survey are summarized in Table-2.

Table 1- Coordinates of 3D seismic survey of the study area, after Rehab, 2016 [9].

Corner	X-Coordinate	Y-Coordinate	Inline	Crossline
A	508992.1013	3397797.2096	39800	9250
B	540142.4367	3423049.2710	39800	17270
C	454690.7916	3452446.2394	48690	39895
D	495841.1270	3477698.3008	48690	46930

Table 2 – Acquisition parameters for the 3D seismic survey area, after Rehab, 2016 [9].

Specifications	Parameters
Type of spread	Theoretical split spread (60+60)
Method	Conventional 3D acquisition
Number of receiver lines	14
Number of active channels per receiver line	120
Receiver station interval	50 m
Source station interval	100 m
Source line spacing	300 m
Receiver line spacing	400 m
Bin size	25 x 50 m
Nominal CDP fold	70
Minimum offset	35 m
Maximum offset	4375 m

Tectonically, Al-Muthanna Province lies within the stable shelf of Salman subzone in the Mesopotamian zone. Salman Zone generally has a shallower basement than the Mesopotamian Zone to the east and the Rutba-Jazeera Zone to the west. It is a part of the Upper Precambrian Terrane that was uplifted during the Late Carboniferous (Hercynian) time and partly during the Early Permian. [10].

Figure 1 – Survey location for the study area [9]

3. Theory

The τ-p transform is an attempt to preserve the seismic data characteristics in the wavefield. A seismic section in the t-p domain can offer a different view in which all subsurface reflectors are illuminated by incident energy of a fixed ray parameter. Working in the τ-p domain gives an advantage so that we can study the different wave modes as a function of their corresponding slowness values (p=1/v), where v is the propagation velocity. The t-p transform is a useful processing tool because it provides an increased separation between different seismic waves (i.e., ground-roll, multiples, P and S waves among others) [11].

A simple roll-along tau-p domain filter is applied to post-stack seismic data to improve coherency. The filter can be used for noise suppression on 2D and 3D data by transforming the input wavefield of post-stack seismic trace into the Tau-p domain. Only the energy from events within the defined range of dips was transformed to the Tau-p domain. Events outside the range of user specified moveouts were eliminated by inverse transforming the data from the Tau-p domain to the t-x domain [12].

The coordinates in the Tau-p domain are the zero-offset time (Tau) and the moveout, that are applied to the far offset trace (p). A p-trace is created by summing constant time paths across all the traces in a t-x domain panel of traces. The traces in the panel are statically time- shafted by an amount dependent on the shift trajectory (TI), with the first p-trace has a p-value of (TI). The next p-trace is obtained by summing across traces that have different shift trajectories (TI) [12]. The shift trajectory (TI) is computed from:

$$\mathbf{TI} = \frac{MAX_p - MIN_p}{NP-1}$$

Where MAXp is the maximum p-trace, MINp is the minimum p-trace and NP is the number of p-traces.

The number of P-traces is calculated using the following equation:

$$NP = (MAXp - MINp) * 2 * fmax * (numx - 1)/\ 1000\ + 1$$

Where fmax is the maximum frequency and numx is the number of x-traces.

The radon transform is performed for any of the parabolic, hyperbolic or linear events, and in the case of Tau-p linear noise attenuation (TPLNA) filter. The radon transform will be used to transform only the linear events. So, the Tau-p transform is a special case of radon transform, where the data are decomposed as a series of straight lines which will be mapped into points in the Tau-p domain [8].

As shown in Figure-2, any linear event in time domain will be transformed into point in the Tau-p domain, eventually forming p-traces. The points in Tau-p domain will be distributed depending on the dip of the linear event in the t-x domain, in which the white line in the figure will be transformed into a point in the center of the Tau-p domain, the yellow line will be positioned in the positive side, while the red line is in the negative side because of the inverse dipping [12].

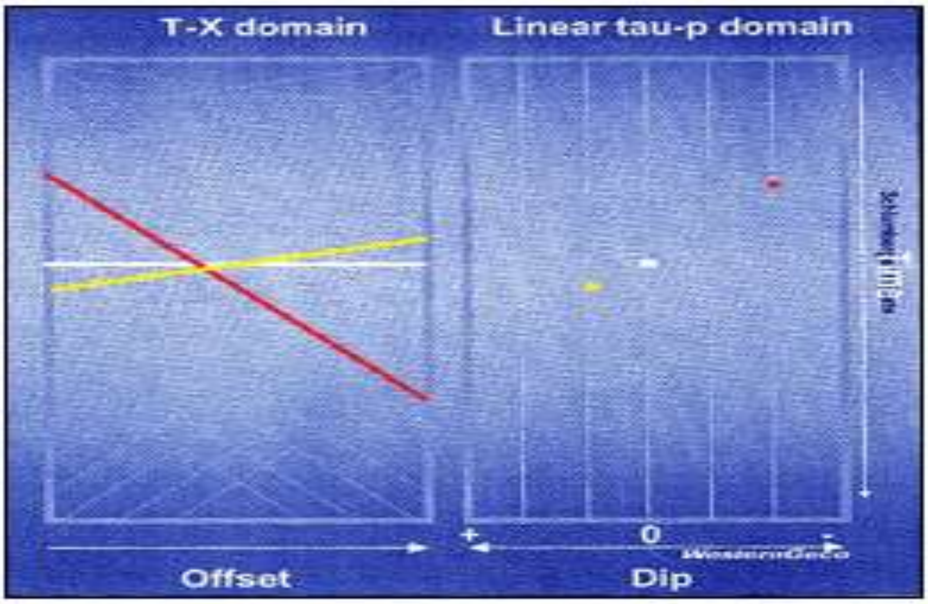

Figure 2 - The Tau-p transform [12]

4. Methodology

TPLNA was applied using Omega Western Geco software to eliminate linear noise within the data. First a normal move-out (NMO) was applied to the shot gathers, then transformed into the Tau-p domain. The velocities applied to the NMO will only affect the signal, hence the desired signal will be transformed from a dipping event into a horizontal, that is almost a zero dipping event, whereas the remaining data (which are, in this case, the linear noise) will remain linear. It is important that the gathers are free of spiky noise, because any spikes that exist in the data prior to Tau-p transform are spread over a wide range of traces within the gather after applying inverse Tau-p transform.

Thus, applying the forward radon transform to the NMO-corrected shot gathers will transform all the signal in the center (small P value), whereas the linear noise which has a larger dipping will be mapped in the far side away from the signal (greater P value). After applying the transformation, Tau-p filtering or muting can be used to attenuate linear noise by dividing the Tau-p transform into pass and reject zones. By allowing the centered events to pass while rejecting the rest, the linear noise can be removed leaving only the desired signal. The pass and rejected zones can be specified either manually or by using velocity parameters. Then the filter will transform the data back to the t-x domain and finally an inverse NMO will be applied. The steps of the procedure for TPLNA filter are summarized in Figure-3 where;

(A) Is a shot that contains linear noise after random noise attenuation.

(B) Applying NMO to the shot (Note that the stretching caused by the NMO is most severe near the first arrival, and diminishes at later times).

(C) Transforming the data from t-x domain to the Tau-p domain using forward radon transform, in which, at this case, the noise should be in the middle and the linear noise is distributed at the sides. The pass and rejected zones are specified manually, as shown by the two red and blue lines.

(D) Muting the noise and allowing only the signal to pass.

(E) Transforming the data back to the t-x domain.

(F) Applying inverse NMO with the same velocity file.

(G) The removed linear noise (A-F).

The required parameters for Tau-P transform are as follows:

- **Min moveout**: smallest moveout at max offset (negative number).

- **Max moveout**: largest moveout at max offset (positive number).
- **Offset** (The parameters above are used to define the range of the filter).
- **Moveout display start time**: the start time of the previously defined range.
- **Maximum frequency to process:** (0-120).
- **Number of P-traces:** either internally computed or manually added.
- **Muting Velocity:** in case of using auto pass and rejection zones.

The Tau-P transform was applied for one time using the parameters shown in Table-3.

Table 3 – Tau-P (Radon) transformation parameters

AGC/applied & removed	500
Transformation Type	Linear
Minimum Moveout in T-X	-3500
Maximum Moveout in T-X	3500
Reference Offset Distance	5000
Number of P-traces	Computed
Muting	Manually

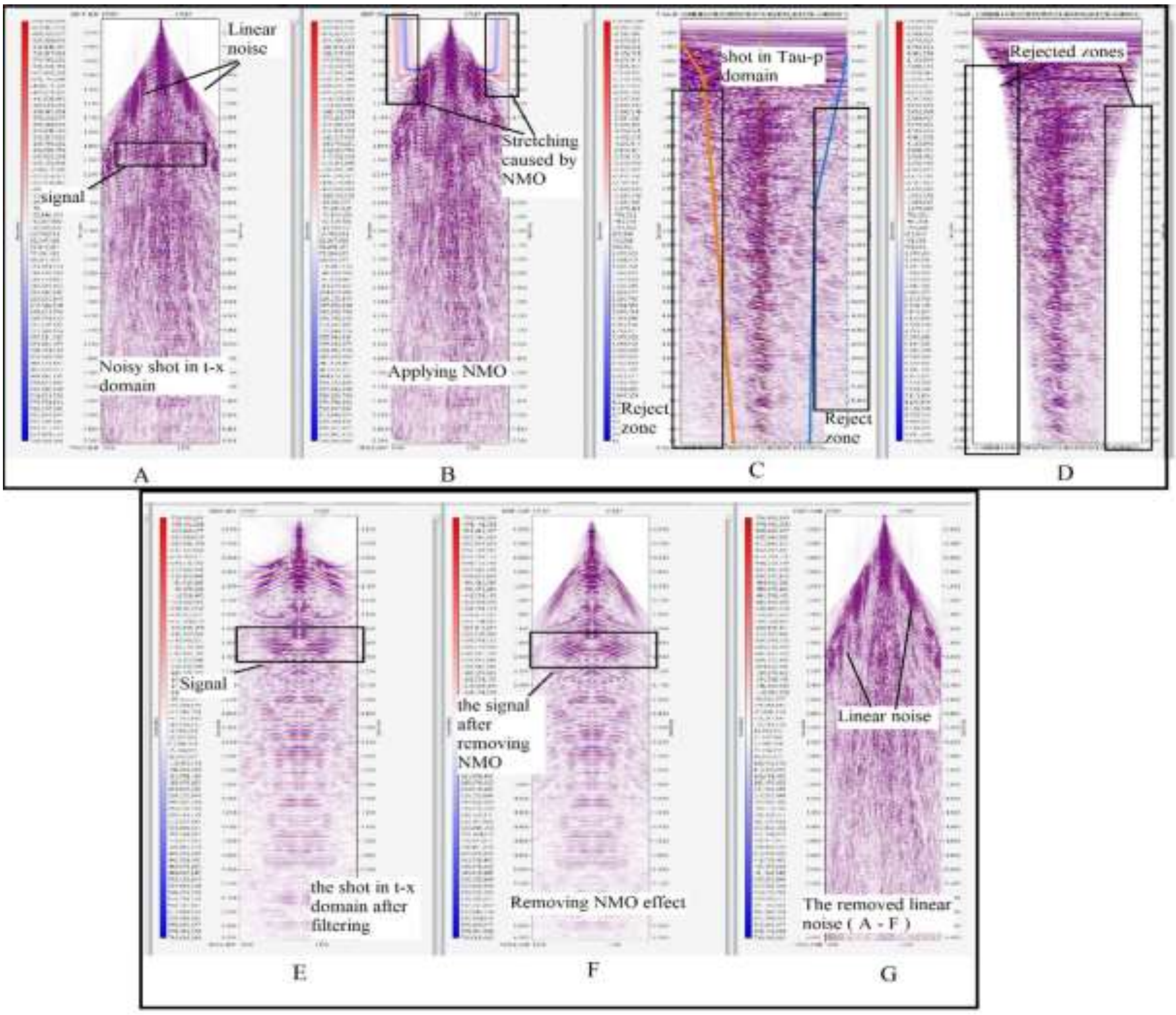

Figure 3 – Steps of TPLNA procedure where (A) a noisy shot; (B) applying NMO (C) transforming to the tau-p domain; (D) muting or rejecting the noise manually; (E) transforming back to the time domain; (F) applying inverse (NMO) and (G) The removed linear noise (A-F).

Automatic gain control was applied in order to clearly observe the data, then the NMO was applied in order to flatten the hyperbolic form of the signal. The results of the radon transform using the above parameters on a shot gather are shown in Figure-4, in which (A) is a shot gather before applying TPLNA, (B) after applying TPLNA and (C) the removed linear noise. The input data for the Tau-p transform are the pre-stack of any type (shot or CMP). The results of applying the filter on a stacked inline section are show in Figure-5.

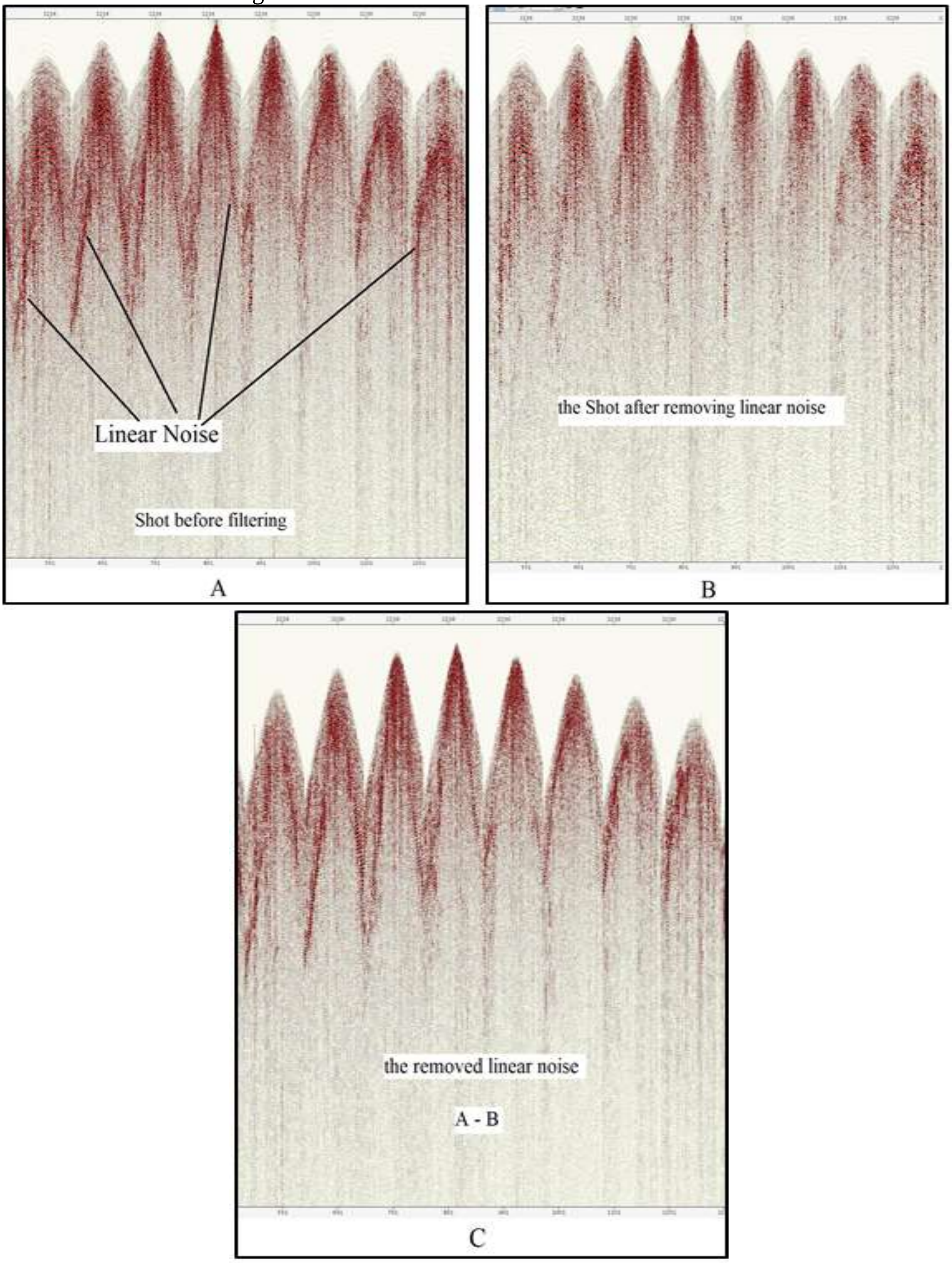

Figure 4 – applying Tau-P linear noise attenuation filter (TPLNA) on a shot 3236 (A) before filtering (B) after filtering (C) the removed noise

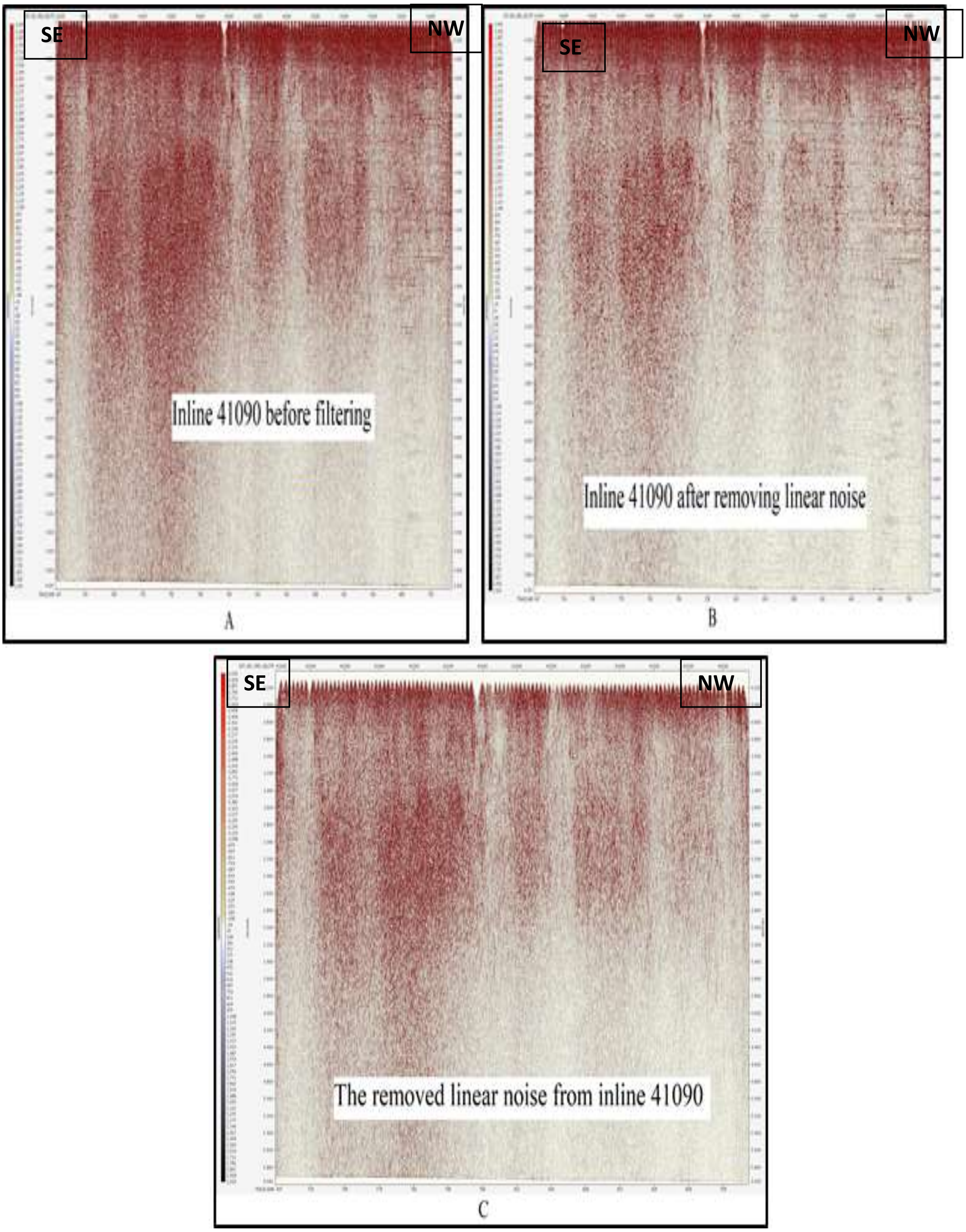

Figure 5 - Applying Tau-P linear noise attenuation filter (TPLNA) on inline section 41090 (A) before filtering (B) after filtering (C) the removed noise.

5. Conclusions

Tau-p linear noise attenuation filter (TPLNA) was proposed to attenuate linear noise from 3D seismic survey of Al-Samawah area south-west of Iraq. There are many methods that can be used for the separation of signal and noise by transforming the data from the time domain to any other domains, but the TPLNA processed on 3D pre-stack and stacked sections was found to illuminate the signal or the primary events much better than those processed on other domains. Because 3D seismic data have irregular offset sampling, the linear noise such as ground roll will lose its linearity.

Therefore, filters such as notch and f-k may have a limited success to attenuate such noises. The proposed filter transforms linear events on time domain into points on Tau-p domain based on their moveout, then rejecting the unwanted data and allowing only the signal to pass. The use of Tau-p transformation to remove linear noise provided very good results on the pre and post stacked data, although not 100% of the noise was removed because severe filtering may affect the data and some of the signal may be lost. Thus, we propose using Tau-p transformation method to remove 3D noise which can be very effective at reducing these types of dominant noises that cover the seismic reflections.

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