DOI: 10.24996/ijs.2019.60.10.12

ISSN: 0067-2904

Pre and Post-Stack Imaging of 2D Seismic Data Using Time Migration for Ajeel Oil field, Central of Iraq

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Abstract

Kirchhoff Time migration was applied in Pre and Post-Stack for 2D seismic survey for line AJ-99N, that is located in Ajeel oilfield in Salah Al-Din Governorate, Central Iraq. The process follows several accurate steps to reach the final time migration stage. The results of applied time migration give an accurate image for the Ajeel anticline reservoir and to improve the signal to noise ratio. Pre-Stack shows a clearer image for the structure in the study area, and the time-frequency analysis insure the result.

Keywords: Pre-stack Post-stack Time migration, Seismic processing, 2D seismic Imaging.

تصوير قبل وبعد التنضيد لبيانات سيزمية ثنائية الأبعاد باستخدام التهجير الزمني لحقل عجيل النفطي ، وسط العراق

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الخلاصة

تم تطبيق التهجير الزمني باستخدام طريقة كيركوف لبيانات قبل وبعد عملية التنضيد لخط المسح الزلزالي الثنائي الأبعاد AJ-99N ، و الواقع في حقل عجيل النفطي ضمن محافظة صلاح الدين وسط العراق. أتبعت المعالجة عدة خطوات دقيقة للوصول الى المرحلة النهائية للتهجير الزمني. نتائج التهجير الزمني المستخدم اظهرت صور دقيقة لطية مكمن عجيل وحسنت من نسبة الاشارة الى الضوضاء. تهجير البيانات قبل النضد اظهر صور اكثر وضوحا للتركيب في منطقة الدراسة وتحليل الزمن-التردد اكد هذه النتائج.

Introduction:

The main objective of seismic data processing is an endeavor to produce an image or section, that represents the geological structure of the earth's subsurface, that is, obtaining a picture of subsurface structure from the seismic waves recorded at the earth's surface [1]. Migration is a term that used in seismic reflection survey which is defined as moving the dipping reflection events to their true subsurface locations and falls the diffractions, so increasing the spatial resolution and create an accurate seismic image of the subsurface [2]. The principle of migration is Huygens's secondary source principle. This is a state that any point on a wavefront can act as a secondary source producing circular wavefronts when viewed in two dimensions. The process of migration is to collapse the apparent secondary wavefronts to

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their points of origin. For example, a point source generates a diffraction hyperbola as shown in Figure- 1, by scanning an appropriate number of adjacent traces, the hyperbola can be collapsed back to the point source by the migration process [2, 3]. The number of adjacent traces scanned is known as the migration aperture. When the seismic velocity is slow, the curvature of the diffraction hyperbola is steep, and consequently, the number of traces required is small. As the hyperbola curvature decreases (flattens) with increasing seismic velocity, the migration aperture also has to increase. The incomplete collapse of diffraction hyperbola occurs if insufficient aperture widths are chosen. It is also important to ensure that the migration aperture is large enough to capture all the required data for a given geological target [4]. Migration aperture is a critical parameter. A small migration aperture causes in destroyed the high dip events as well as the amplitudes would change rapidly and the random noise would appearing as pseudo-reflection event [5]. An aperture of seismic migration is considered the spatial range of data that contributes to calculation [6] causes an increasing noise and amplitudes in the shallower part of the seismic section. Due to misplace information in shallower part as well as the signal to noise ratio would also be decreased in case of the noisy seismic section. Choosing the perfect migration aperture should take into account the velocity of the section and dip degree for reflection event. The actual migration aperture is time-varying so the shallower portions of a section may be adequately migrated [7]. The dip-limited Kirchhoff migration may also be illustrated in the depth section when the velocity is constant. Figure-1 contains a scatter point (G) located at the depth of (z_0). A source-receiver pair is moving across the surface with a displacement (x) from the surface location of the scatter point. A record section on the depth plane is generated by mapping the travel distance in the (z-direction). The relationship between the displacement (x) and the travel distance (z) from the scatter point (G) to each source-receiver pair was derived as; [8]

$$\boldsymbol{Z^2 - X^2 = Z_0^2 \;\; and \;\; tan(\alpha) \; = \; sin(\beta)}$$

Those hyperbolas can be considered as the migration operators while Kirchhoff migration is applied in the $(x - z)$ domain. If the migration aperture (angle GOB orGOA) is chosen as (α) that is equal to the angle (GDF) or (GCE) is defined as β', the following relationship can be directly derived as; [9]

$$\boldsymbol{x = z\,tan(\alpha) = z\,tan(\beta') \; or \; tan(\alpha) = tan(\beta')}$$

The migrated dip-angle has properties that are fortunate for taking both issues the aperture position and its width in sight. A reflection event has a concave form with an apex whose position corresponds to the reflector dip. The event summation in the dip-angle direction produces an image in agreement with the stationary-point principle [10].

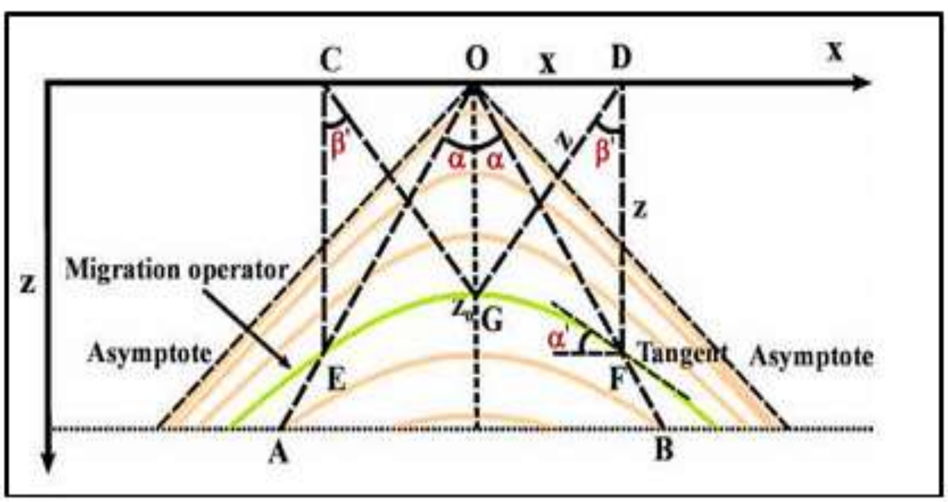


Figure 1- A point source and angle relationship with the migration operator. [9]

To limit aperture in the dip-angle and to restrict summation to stationary points, applied an automatic slope estimation followed by muting. Aperture size was defined on the basis of wavelet bandwidth [11].

The Kirchhoff migration can be limited to various maximum dips. The smaller impulse response gives the maximum suitable dip, as well as the smaller the aperture. This arrangement of maximum aperture width and maximum dip limit determines the actual effective aperture width used in migration. In particular, diffraction hyperbolas along which summation is done were reduced beyond the specified maximum dip limit [12]. For the dip-limited Kirchhoff migration, the dip limit is directly proportional with its summation aperture. Specifying a dip limit will confine the dip on the migration operators and hereby limit the dip on the migrated section [9].

Kirchhoff migration or Diffraction migration is a statistical method. Kirchhoff migration is based on the observation that the zero-offset section consists of a single diffraction hyperbola that migrates to a single point. Migration usually involves summation of amplitudes along a hyperbolic path [13]. Kirchhoff migration depends on the secondary Huygens' Principle. The summation of these minor waves determines the form of the wave at any subsequent time. The wave front, in a homogeneous media, wave front is a semi-circle when the velocity is constant for one trace that recorded as in Figure-2, [14].

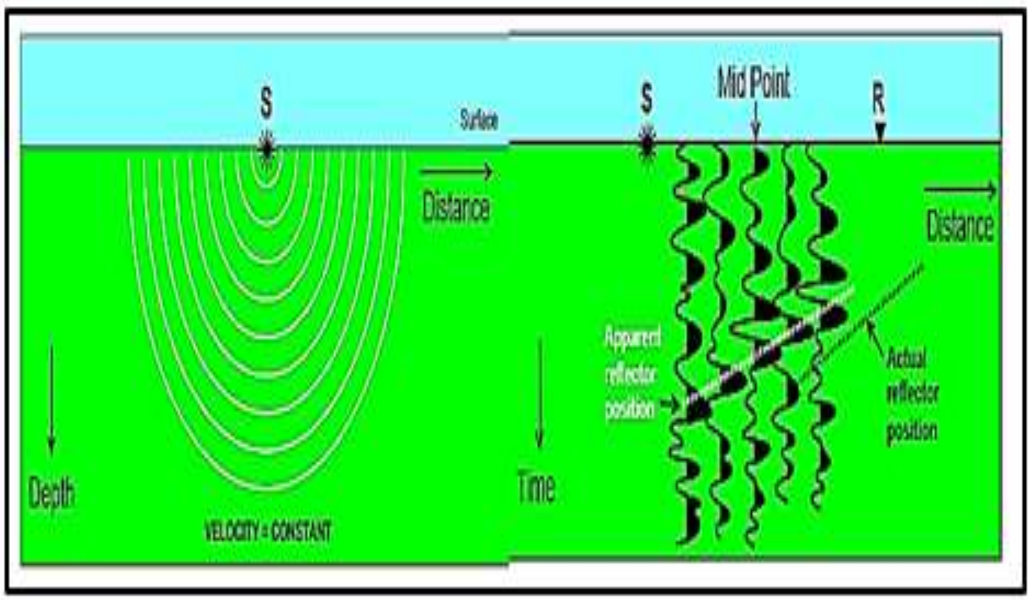


Figure 2- The geometry of a scatter point. A scatter point scatters incoming energy back in any direction, when the wave propagation velocity is assumed to be constant. [14, 15]

The benefit of this method is that it has good performance in case of steep-dip structures. The method performs poorly signals when the signal-to noise ratio is low [7]. In the Kirchhoff time migration, a point on a migrated time section (x, τ) is often considered as a scatter point. Although the extension of scatter point concept from depth domain to two-way vertical time domain is not perfect when velocity varies, Kirchhoff migration equation can well approximate the travel time response of a scatter point for most of the cases when the subsurface structure is not very complex. [15]. The migration velocity for migrated time imaging in a time domain scatter point (x, τ) is actually defined mathematically in terms of collecting most amount of diffracted energy from the corresponding depth domain scatter point, often called the double-square-root (DSR) equation, and it can be expressed in CMP and offset domain as; [15, 16].

$$\boldsymbol{T} = \sqrt{\frac{\boldsymbol{t^2}}{\boldsymbol{4}} + \frac{\left(\boldsymbol{x_{off\,surface}} - \boldsymbol{h}\right)^2}{\boldsymbol{v^2}}} + \sqrt{\frac{\boldsymbol{t^2}}{\boldsymbol{4}} + \frac{\left(\boldsymbol{x_{off\,lateral\,surface}} + \boldsymbol{h}\right)^2}{\boldsymbol{v^2}}}$$

Where: $\boldsymbol{x_{off\,surface}}$ denotes a CMP surface location, h denotes the half source-receiver offset and $\boldsymbol{x_{off\,lateral\,surface}}$ denotes the lateral surface distance between a CMPs location and the scatter point(x, τ).

Study Area and Data Available:

Ajeel oilfield (Figure-3) [17, 18], is located in Salah Al-Din Governorate, 30 Kilometers to the north east of Tikrit city and to the east of Tigris River between the cities of Tikrit and Kirkuk, $(34°53'2"N)$ longitude and $(43°46'41"E)$ latitude. The field was discovered after the seismic survey done at Hamrin -Ajeel region in the years (1975-1979).

Tectonically, Ajeel oil field is located at the low folded zone of the Zagros Fold Belt with transition near platform plane of the Mesopotamian Foredeep Basin [19], Structurally, Ajeel has no surface expression and the structure entirely confined to the subsurface. It consists of a double-plunging anticline trending NW-SE with the closure of 150 m in height and 10 km long on top of the Quinta Formation. The Ajeel oilfield is part of many fields of structurally oriented NW-SE within the northern part of adjacent to the low folded zone of the Zagros Fold Belt [20].

The available data for the current study include a seismic line of 2D seismic surveys of Ajeel area. This line is part of the 2D seismic survey completed in 1979 by the Iraqi Oil Exploration Company. In the current study, the line AJ-99N was reprocessed in 2018 with modern methods by using the Geovation seismic processing system in the Iraqi Oil Exploration Company (IOEC), center of seismic processing, ministry of oil.

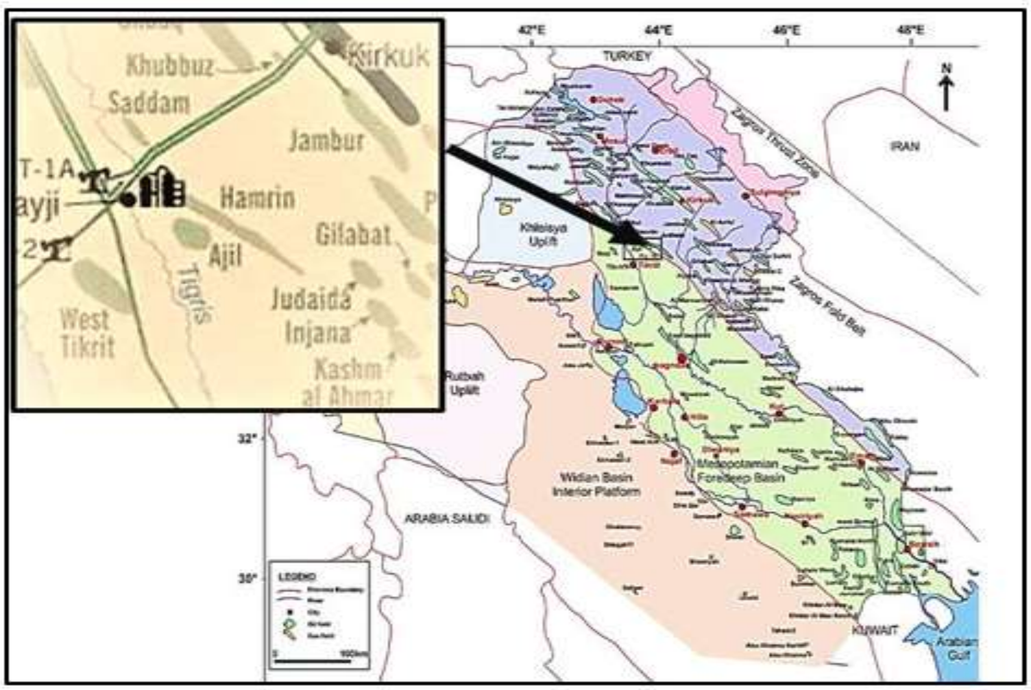


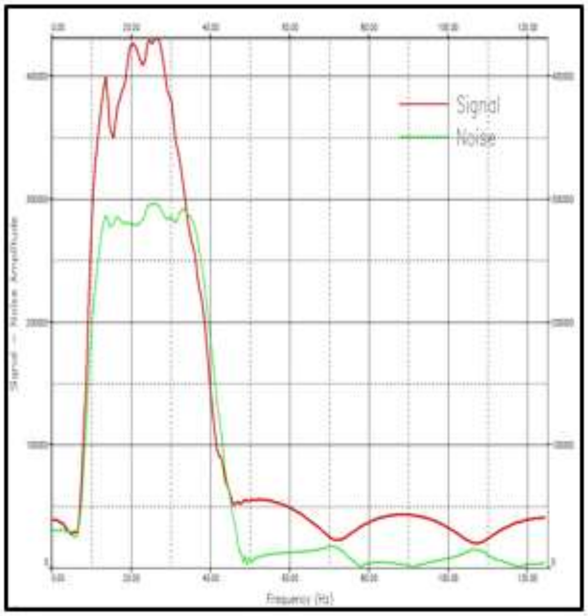
Figure 3- Location of the study area. [18]

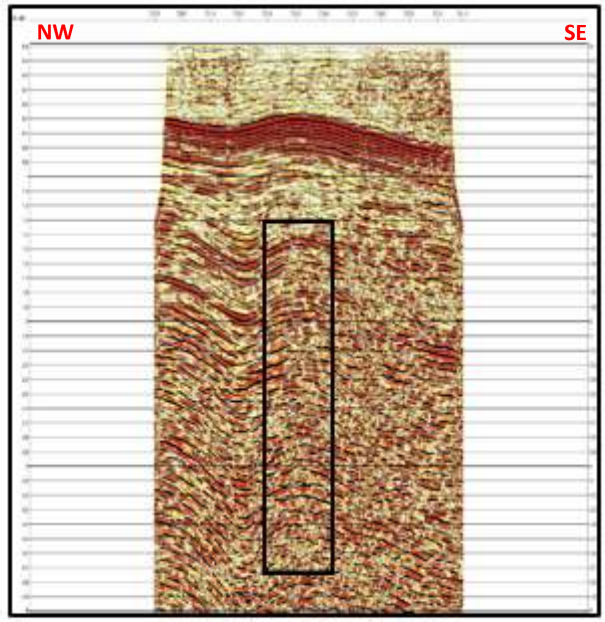
The length of the seismic line is 24.4 km towards NW-SE and along with the strike line of ajeel anticline, the field parameters are: source type is dynamite, number of channels are 48, coverage is 1200%, datum plane is 150m (A.S.L.), spread type is center, sampling rate is 2 ms, recording length is 5 sec, trace spacing is 100m, trace length 85m and the offset is 100m.

Data processing and Results:

AJ-99N survey line has been reprocessed by using Geovation seismic processing system in the Iraqi Oil Exploration Company (IOEC). The seismic processing divided into three steps which are; data reduction, geometric correction, data improvements and finally imaging. The processing that where applied on AJ-99N line is; Demultiplex, Geometry Characterization, Static Correction, Gain Applications, Noise Attenuation, Deconvolution, Common - Midpoint (CMP) gathering, Normal - Moveout Correction (NMO), Dip - Moveout correction (DMO), Velocity analysis, Residual Statics, Stacking and imaging which is includes post-stack and pre-stack migration . Each one of the processing steps has the purpose to remove the distortions that happen in the seismic section. In Kirchhoff migration method, three parameters should be fixed and applied on all the seismic section which are; migration aperture, migrated velocity and target depth.

As shown in Figures-(4A and 4B). The results of the processing sequence are final with residual statics correction stacked seismic section, that is correct any residual time shifts to flatten NMO-corrected events on the seismic section with a signal to noise ratio spectrum.





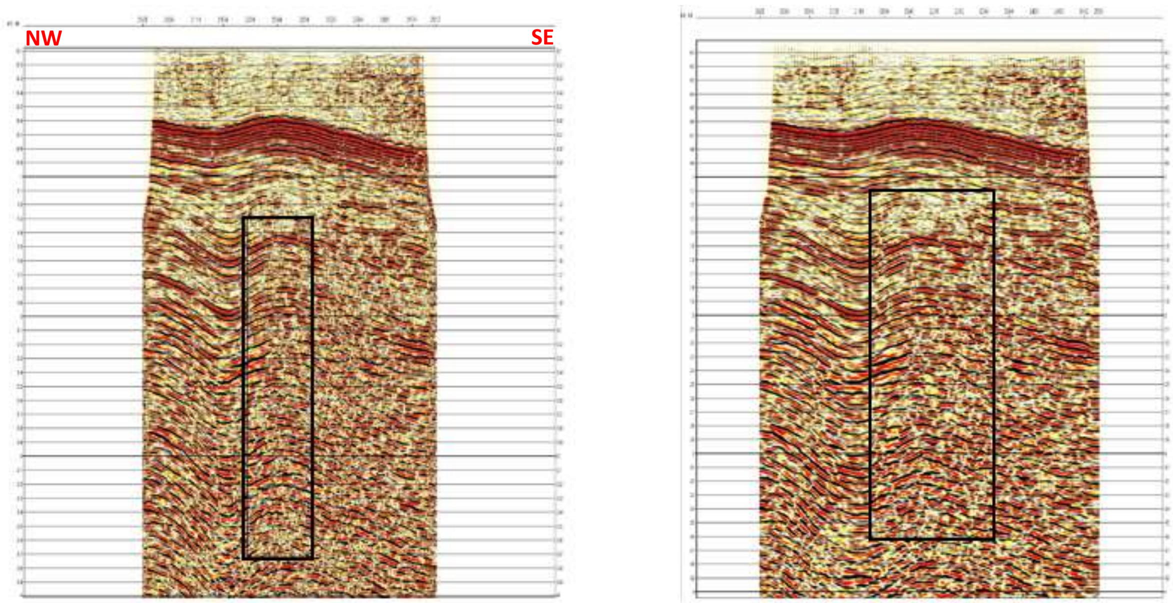
A B

Figure 4- AJ-99N seismic line after applying the processing steps. A) Signal to Noise ratio spectrum, B) Seismic section.

After finishing the processing steps, the final processing in imaging which is dealing with migration, in this study Kirchhoff migration was applied for Post-Stack and Pre-Stack migration.

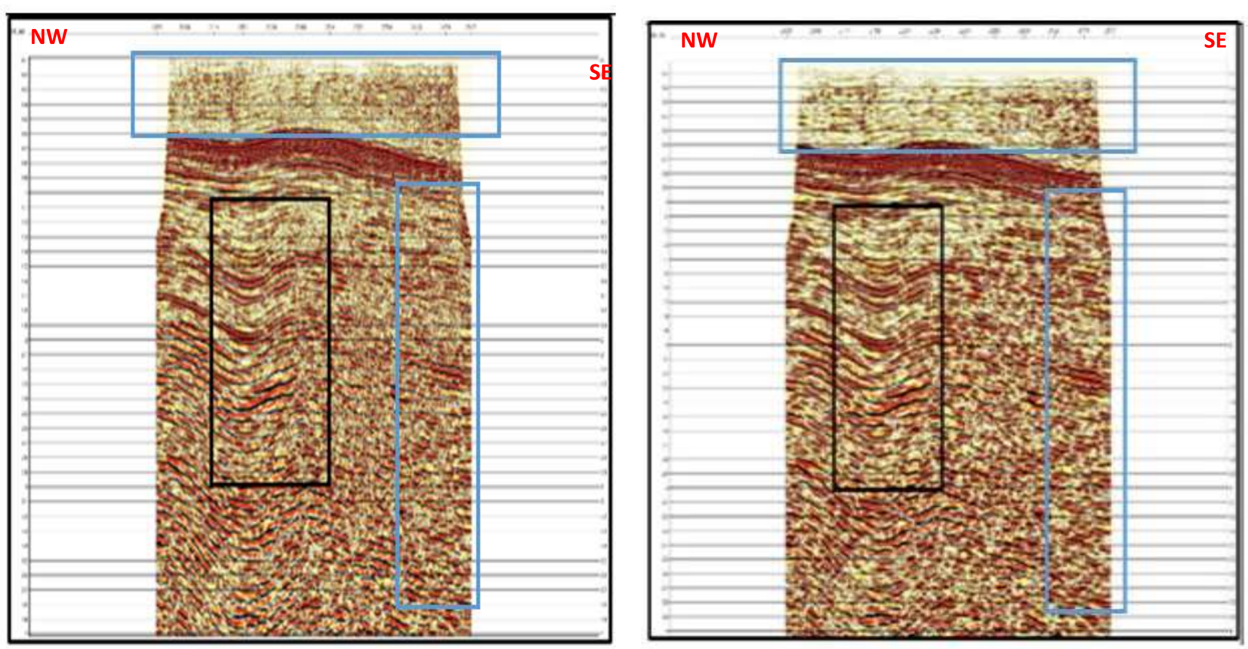
In Post-Stack Time Migration ($PSTM$), and after residual static, one can go within the post-stack time migration where it was applied on the residual stack to get a true image in progress of the working flow. Here, Kirchhoff migration method was applied on stack data with a parameters: migration aperture 2000m after testing from 1000 to 3000m with increment 500m, dip angle cut of migration operator equal to 30 degrees which also tested from 10 to 60 degree and velocity smoothing and interpolation was 100% for tested values from 90% to 110% with increment 2%. All these selected parameters (2000m, 30 degrees and 100%) are the best result for the migration process. Post-stack migration shows a better stack subsurface image than residual stack (Figure-5).

The synclines structure in the seismic image along the time (1.3-3.2 sec) image in the CMP range (2025-2513) m becomes extra broadening after migration. So that, the Kirchhoff migration correct in the structural geology and relocate the seismic data to the true position. The imaging process returns with side effect or dip noise in the edges area because of the migration operator. As known, it could be removed with dip removal filter which called $F-K$ filter of parameter fan dips (-8.8) as shown with blue rectangles in Figure-(6B). For the quality control (QC) of migration process, the curve of signal with frequency and the noise curve with same range of frequency as in Figure-7 which is a noticeable large difference of residual stack and migration stack. The QC shows successful working of migration process because it increases the signal to noise ratio and made the distribution of amplitude more homogenous after applying migration.



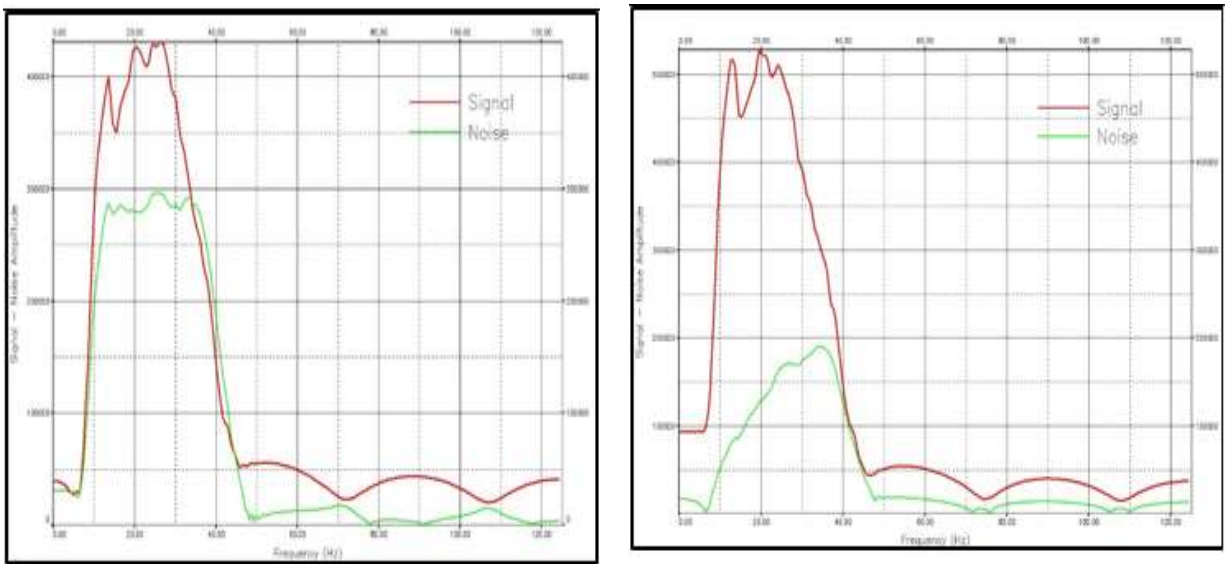
A **B**

Figure 5- A) final with residual statics correction stacked section, B) Kirchhoff migration stacked section.



A **B**

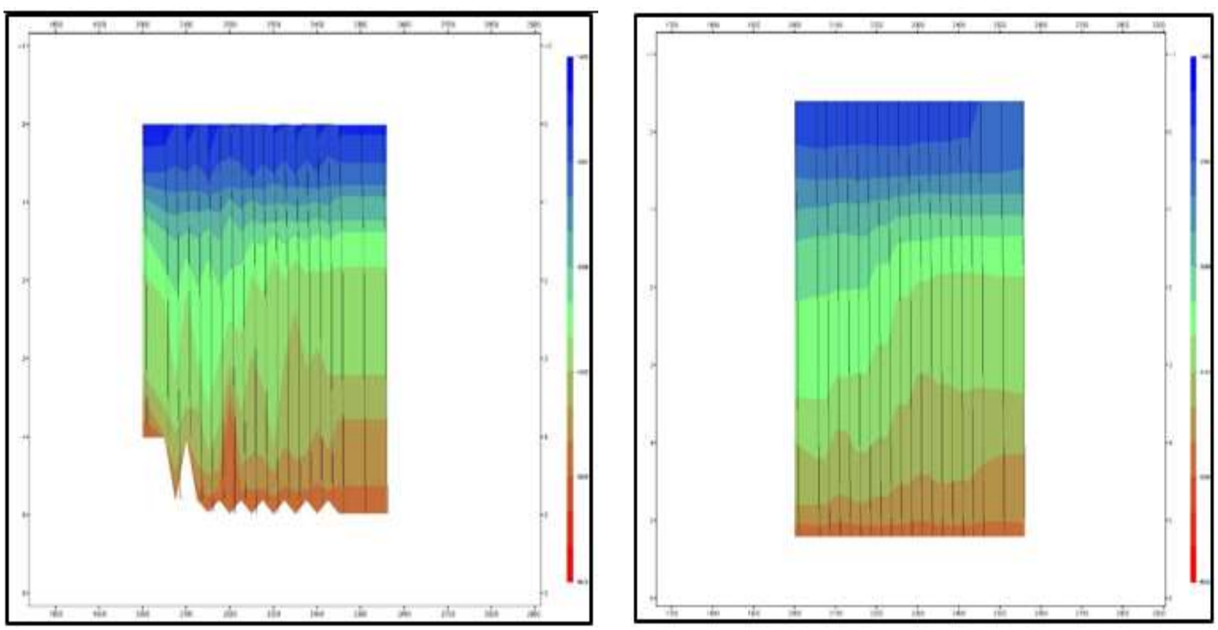
Figure 6- A) Migration stacked section without dip removal filter, B) Migration stacked section with dip removal filter.



A **B**

Figure 7- Signal to Noise ratio curve for, A) Stacked Section, B) Migrated stacked section.

In the Pre-Stack time migration ($Pre-STM$), the processing has been done on the offset classes before stacking operation, which is a type of data sorting depends on the offset unit of the section. Ajeel seismic survey area subdivided into 100m offset as a single data processing with migration operations. In this situation, the velocity analysis also needed to be re-picked and smoothing to get better velocity section before migration processing, as shown in Figure-8.



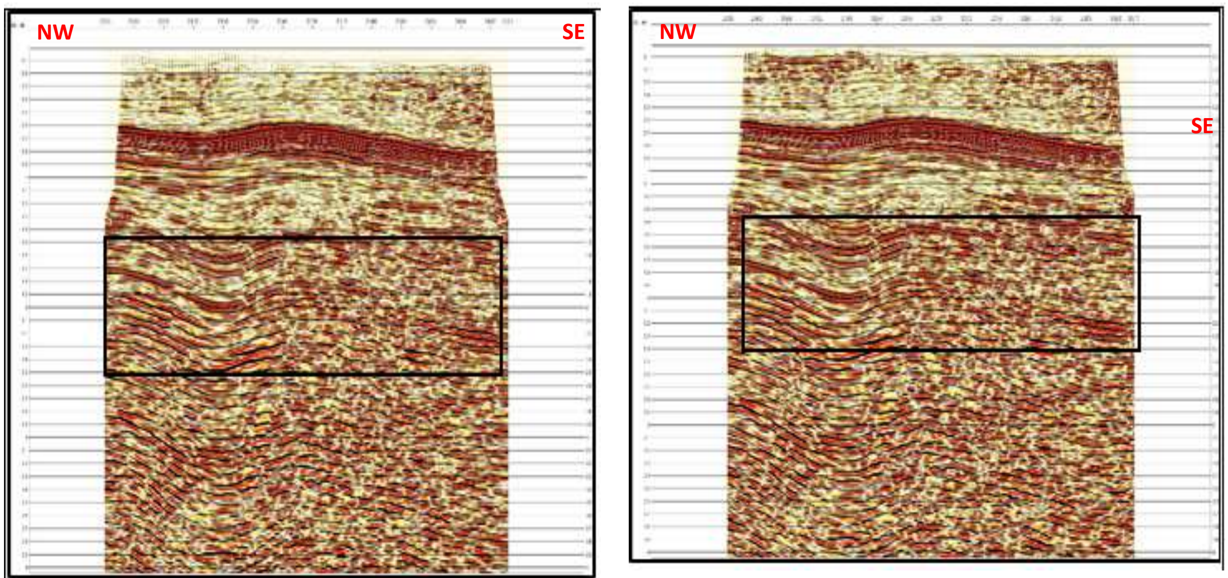
A **B**

Figure 8- Shows the ISO-velocity section, A) before smoothing, B) after picking and smoothing.

The parameters were used in Post-Stack Migration are also applied in the Pre-Stack Migration processes and the results of Pre-Migration process should be lookup in stack section which gives a clearer displayed section so as to compare with previous stacked sections. The results of this process is a migrated stacked section in Pre-migration state; compared with the Post-stacked migrated time section as in Figure-9. Comparison of pre and post stack sections in time-frequency domain shows a removal of noise in the post stack migrated section using a process for dip dependent median filter (DDMD) with blue circles as in Figures-(10 and 11).

Discussion and conclusions:

The small lateral velocity variation in Ajeel oilfield survey area leads to make the comparison between PSTM and Pre-STM on the stacked seismic data. The Pre-STM shows much reliable subsurface image with small changes in the edges of the seismic line. Also, time-frequency analysis shows a clear evident that Pre-STM is better than PSTM. Due to the type of subsurface structures and structural complexity, the dipping events in the stacked migrated section was shortened, steepened and moves the dips to up-dips, anticlines are narrowed, synclines are boarding and the diffractions collapsed to points as in faults. Thus, the scattered waves that appear in the stacked section should not be treated as noise and this is a fatal mistake.



A B

Figure 9- Shows the stacked section in A) Post-Stacked migrated section, B) Pre-Stacked migrated section.

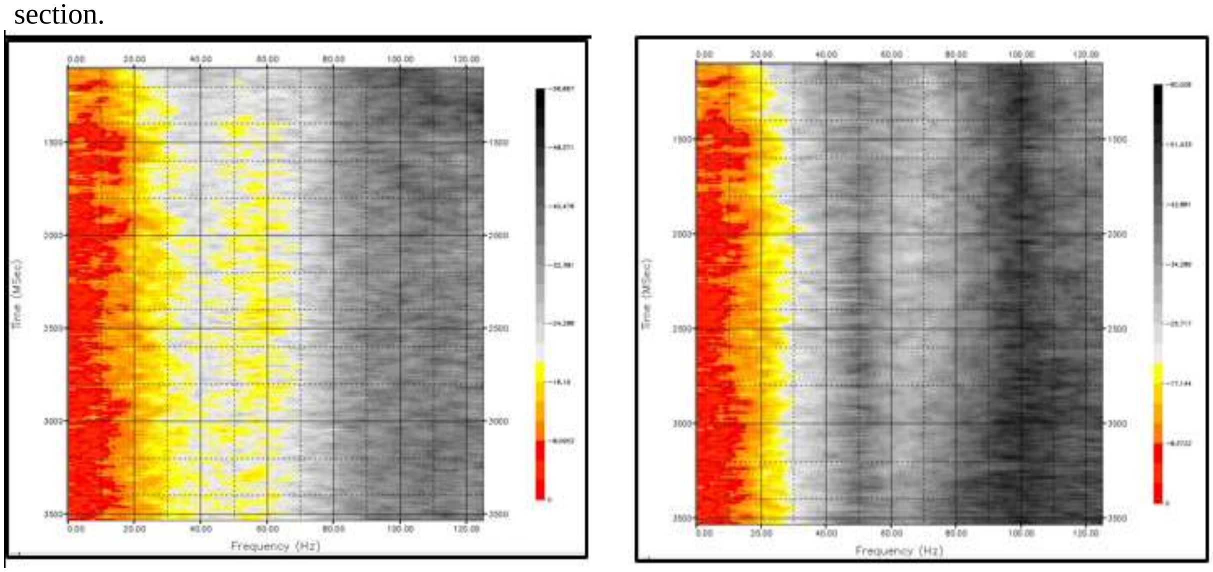


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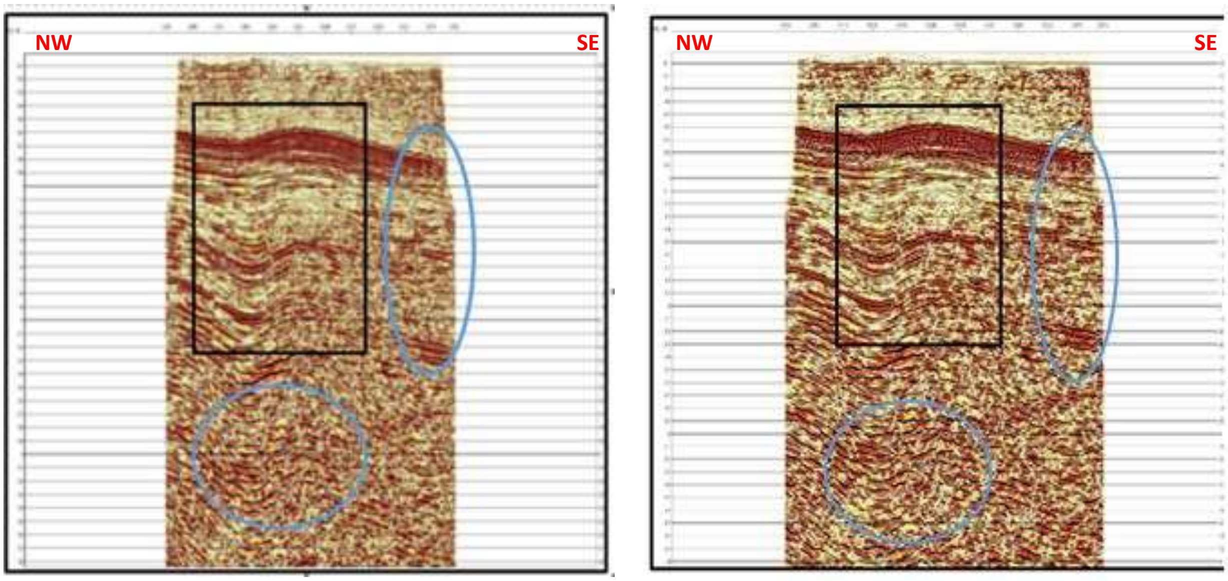
Figure 10- Shows the time-frequency stacked section in A) Post-Stacked section, B) Pre-Stacked section.



A B

Figure 11- Shows the Pre-Stacked time migration section in, A) Pre-Stacked section with DDMD filter, B) Pre-Stacked section without DDMD filter.

For simple features without dipping and lateral velocities variations, Post-stack and Pre-stack give the same image for the subsurface features. As well as complex features with higher dips and good lateral velocities variations the Pre-Stack is better than Post-Stack. The PSTM is faster in processing than Pre-STM; but the results may be little resolution than Pre-STM. One needs to be concerned with many aspects in the geometry of the field survey; such as the length of the seismic line which must be satisfactory to allow steeply dipping event to migrate to its true subsurface location; otherwise, an error will occur when the recorded profiles are to short. In areas with complex geological structures trace spacing must be small enough to prevent spatial aliasing of steep dips at high frequencies. Also random noise at latter times on a stacked section (when migrated), possibly can be dangerous for shallower data that makes a pseudo seismic events. One may have to compromise on migration aperture for deep data to prevent this problem to occur.

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