https://doi.org/10.26682/sjuod.2023.26.2.11
Journal of University of Duhok., Vol. 26, No.2(Pure and Engineering Sciences), Pp 118-132, 2023

PROCESSING AND IMPROVEMENT OF 2D SEISMIC DATA BY USING PRE-STACK AND POST-STACK TIME MIGRATION, KURDISTAN REGION, IRAQ

ZHIMAN **F**ALAH **S**ULAIMAN* and **B**ABAN **M**USTAFA **Y**OUSEF**
*Dept. of Applied Geoscience, College of Spatial Planning & Applied Sciences, University of Duhok, Kurdistan Region–Iraq
**Dept. of Geology, College of Science, University of Duhok, Kurdistan Region–Iraq

(Received: May 7, 2023; Accepted for Publication: August 14, 2023)

ABSTRACT

The accurate interpretation of seismic sections in areas with complex subsurface geology, presents numerous challenges including diffractions, inaccurate reflectors position, uncertain seismic amplitudes and noisy lateral discontinuities. Consequently the interpreter unable to construct and identify the subsurface geology from the seismic image. In order to create an accurate and illustrative subsurface image this study aimed in processing of one line of 2D raw reflection data, from Kurdistan region, northern of Iraq. The processing methodology consists of two main procedures, pre-stack and post-stack time migration. Different parameters are tested in all processing stages in order to compare and evaluate their efficiency in seismic data improvement. The results showed that the post-stack time migrated section showed great improvement of subsurface image comparing with stacked section without migration. While the pre-stack time migration presented better subsurface image.

KEYWORDS: Seismic Reflection, 2D survey, Processing, Migration, Pre-stack time migration (PSTM), Post-stack time migration (POSTM).

1. INTRIDUCTION

The processing of seismic data is a sequence of statistical and mathematical procedures that are applied on acquired raw seismic data for obtaining more easily interpretable data in order to achieve useful geological information (Al Sadi & Baban, 2020). In seismic data processing, migration is a term used for the process which moves the dipping reflections to their true spatial locations with correct amplitudes and dip. Moreover collapsing the diffraction energy (diffracted events) into the scatter points (source point) and allows the interpreters to define, describe, and explain the geological features such as faults and other structure features, while enhancing the resolution of horizontal events (Yousefzadeh, 2013; Obaid et al., 2020). The Process of migration can be applied in two stages; before the process of staking (pre-stack migration) and after the stacking (post-stack migration) in time or depth domain. In Post-stack Time/Depth migration process, the amount of seismic data considerably reduces after stacking process, therefore subsequent migration of this data is less cost compared with pre-stack migration. The pre-stack seismic migration is reconstruction of subsurface structures directly from measurements at the surface of the earth. The advantages of this process mostly appear in areas with steep dip faults and complex geology (Ristow et al., 2002). Conventional imaging of seismic data processing includes three steps: Normal moveout (NMO), Stacking of data and Post-stack migration. After that, in order to resolve the dip consistency problem in velocity estimation and the dispersal of dipping reflectors on common midpoint (CMP) gather, Yilmaz and Claerbout (1980), introduced pre-stack partial migration which is now known as the dip-moveout (DMO) correction. Hale (1984) and Deregowski (1986) added DMO into conventional seismic processing methods (Zhang et al., 2006). The conventional processing method is not efficient in case of complex subsurface structures and lateral velocity variations, (Zhang et al., 2004). While, pre-stack migrations can handle the variation in lateral velocity, moreover is the best method for imaging complex subsurface structures. Thus in order to get a better imaging section, correct velocity model is needed (Bednar, 1999; Guo & Young, 2004).

In this study Kirchhoff algorithm of migration is used which is one of the most common migration methods used in seismic data processing.

The Kirchhoff migration method is applicable to both pre-stack and post-stack processing stages for 2D and 3D dataset (Dondurur, 2018). This method is based on Huygens principle and uses integral form of wave equation (Figure. 1), in which, the seismic reflector is assumed as if it is composed of nearly placed diffractions point. Therefore, the apex of diffraction curve is the position of the true reflector point and the

Kirchhoff migration works as the summation of the energy that produced by each Huygens secondary source and map it into source point (Bancroft, 2007; Smitha et al., 2016).

Obaid & Al-Rahim (2020) in a study of 2D seismic section in Ajeel oilfield central of Iraq, applied the Kirchhoff method in pre and post stack time migration. The results of the study provided an accurate subsurface image of Ajeel anticline reservoir. Furthermore, the pre-stack migration showed clearer image.

Shiya (2021) by applying Kirchhoff Pre-stack depth migration updated the 2D seismic data of Khashim Al-Ahmer Gas Field, in order to perform subsurface imaging of the studied area and to recover the seismic energy that reduced by different attenuation factors. The results showed the usefulness of pre-stack depth migration as the studied area was with complex geology.

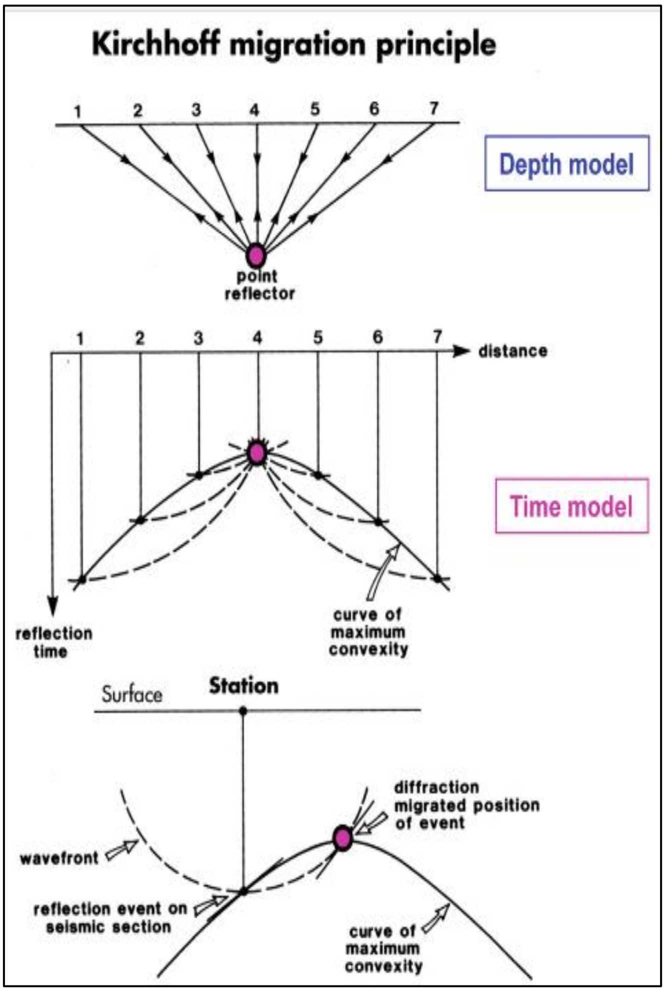

Fig.(1): Principle of Kirchhoff migration method (Veeken & Moerkerken, 2013)

2. MATERIAL AND METHODS

2.1. Study Area

The study area is located in the northwest part of Iraq, represented by Zakho area of Kurdistan Region, which includes the well-known low relief Tawke anticlinal structure (7 km) to the west of Zakho town. Tectonically this anticlinal structure is located within the High Folded Zone of the Western Zagros Fold-Thrust Best (WZFTB) (Figure.2), on the unstable shelf of the northeastern Arabian Platform (Mamaseni et al., 2019). Stratigraphically, this area consisting of rock units belong to the Middle – Late Miocene age of the Eleventh Arabian Plate Tectonostratigraphic Megasequence (TMS AP11), which include the main clastic sediments of Fatha (Lower Fars), Injana (Upper Fars), Mukdaddiya (Lower Bakhtiari), and Bai Hassan (Upper Bakhtiari) formations in addition to the Quaternary Alluvium deposits (Bamerni et al., 2021).

The above mentioned rock units are exposed with low altitudes within three main structures in the investigated area; Tawke anticlinal structure with Zakho syncline to the north and Khabour syncline to the south (Figure. 3). The Tawke anticlinal structure is within an edge of the Zagros sedimentary, it is asymmetrical, double plunging anticline with E-W trending of axial direction with steeper northern limb, the axial length reaches about 23 km (Al-Mosawi, 2007; Al-Moadhen, 2009). The Tawke anticline is truncated by an approximately ENE-WSW trending fault. The fault which extends for 13 km truncates the fold axis with an acute angle (about 20°). The nature of the fault is not clear, but it shows a possible combined thrust and strike-slip components (Sissakian, 1995; Al-Moadhen, 2009).

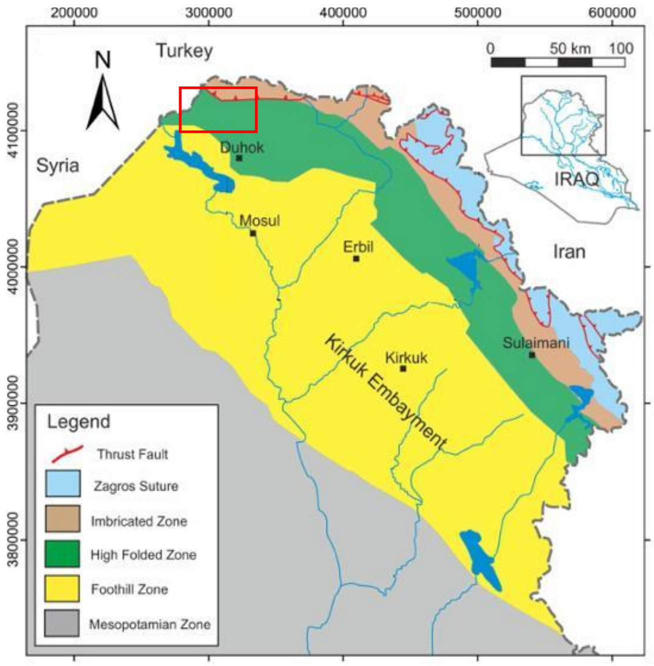

Fig.(2): Iraqi Kurdistan Region tectonic map. The study area is showed by the red square (After Jassim & Goff, 2006)

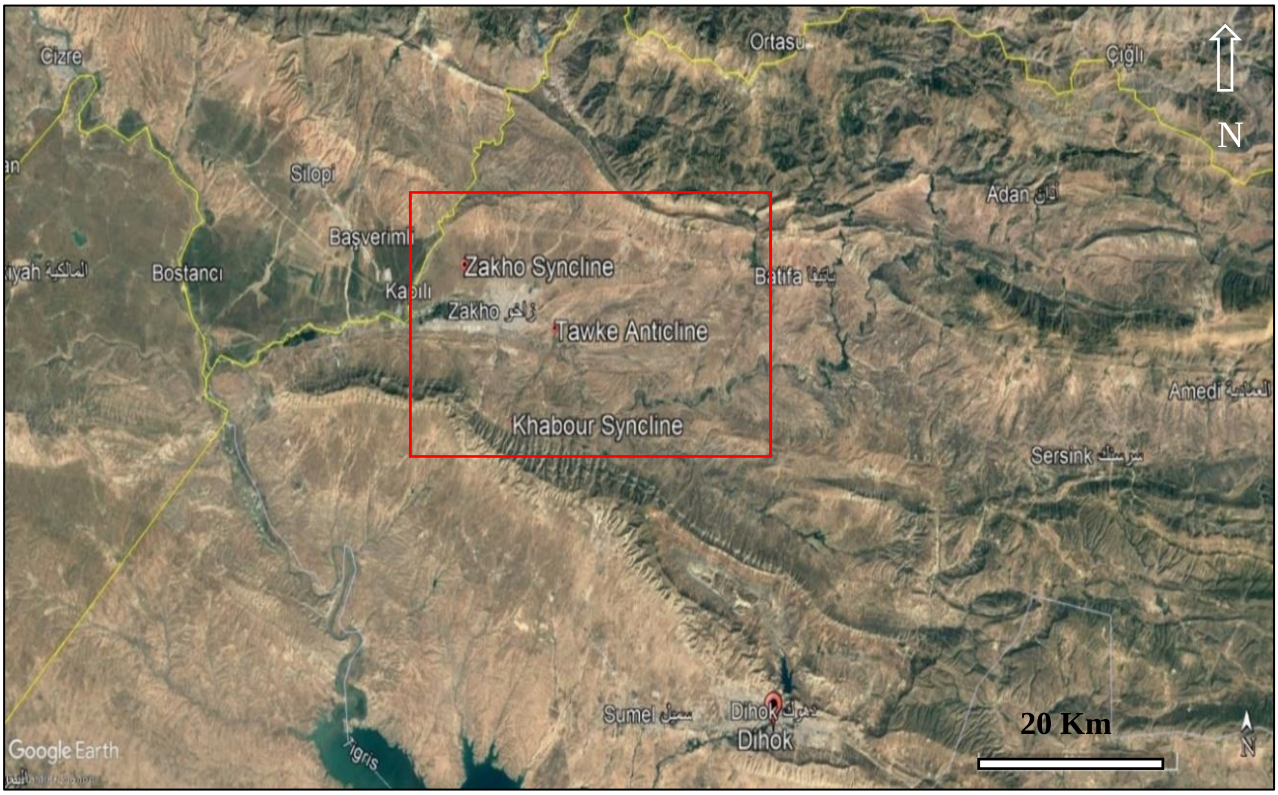

Fig. (3): Satellite image shows the main geological structure within the studying area. (Google Earth Pro, 21/02/2023)

2.2. Data used and processing software

In current study a single line of 2D raw seismic reflection data provided by DNO Oil Company in the form of SEG-Y file format is used (Figure.4). The processing is complete processing system for large-volume marine or land seismic surveys of 2D or 3D, pre-stack and post-stack data. It utilizes geophysical algorithms, analysis tools and an enhanced parallel processing basics to provide large volumes of processed data quickly (Landmark, 2013). The software operates on Linux operating system. The most important properties of this software is the flow editor where you can create a flow with suitable modules from the software "Process list". This list includes key processing stages such as, "Geometry/Headers", "Editing/Muting/Noise " "Data Input/Output" and additionally, includes some subsections within this main sections (Reiner, 2018). Figure .5 shows the processing flow that followed in this research.

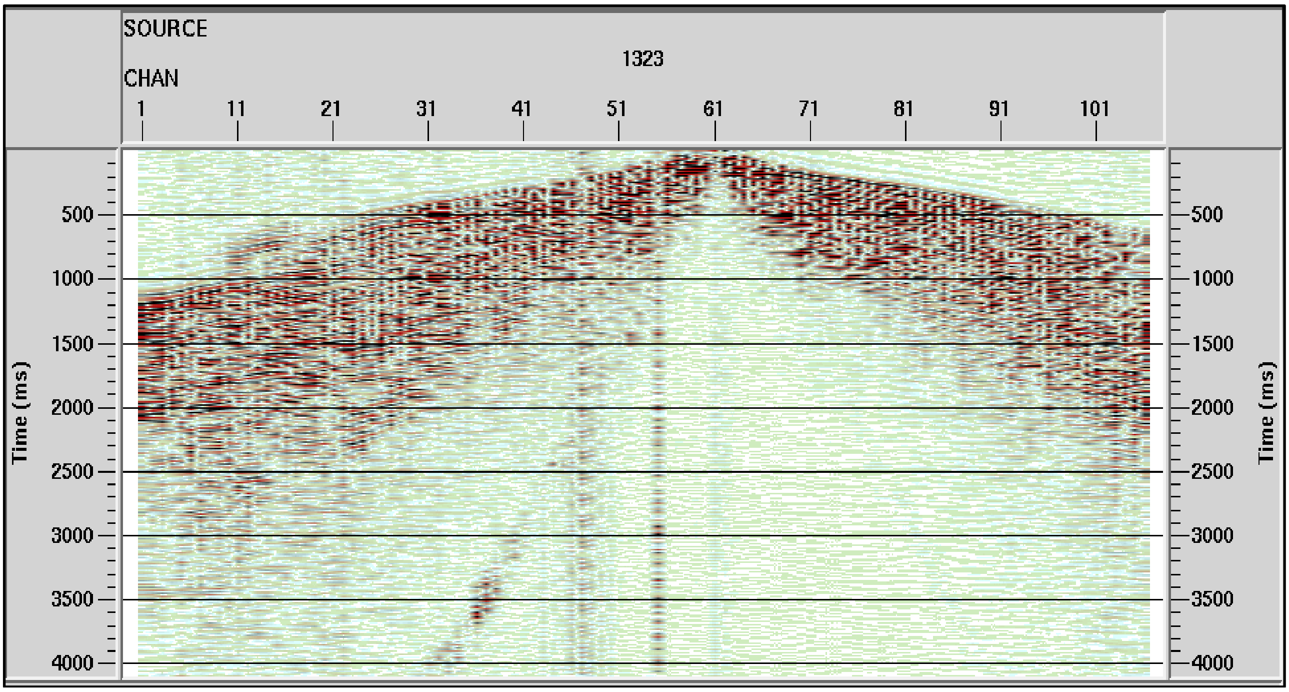

Fig.(4): Trace display of 2D raw data

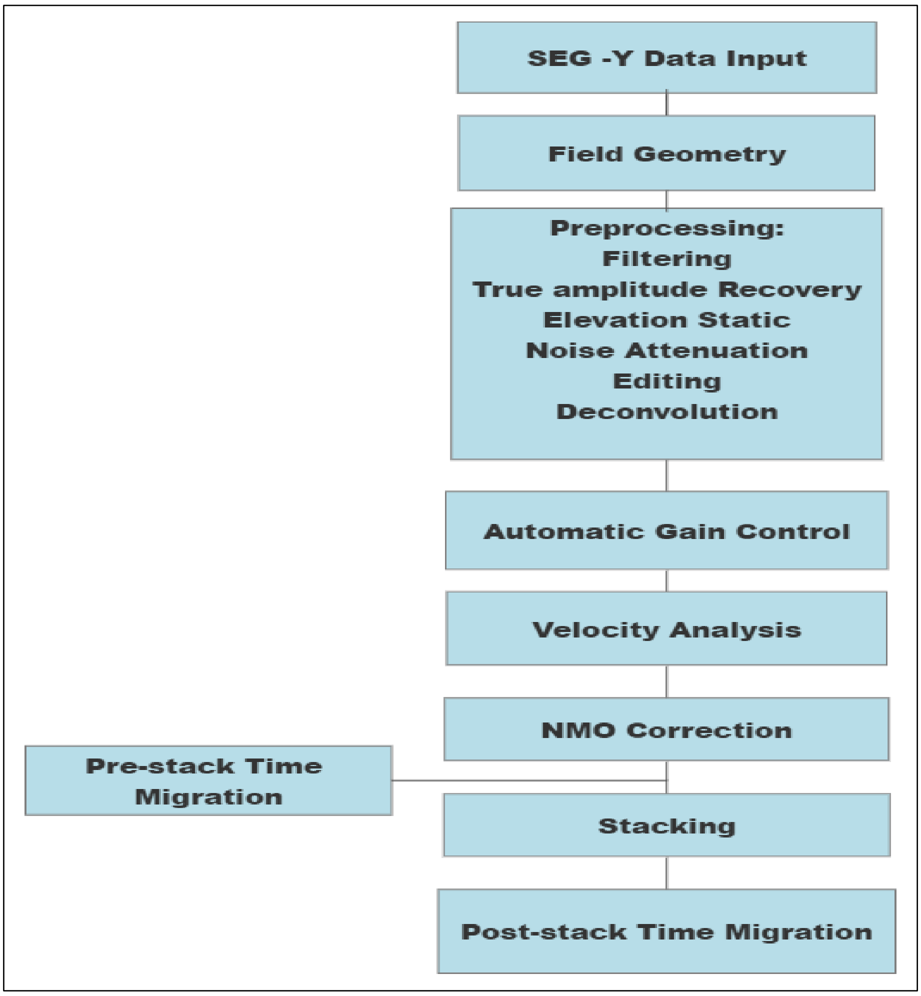

Fig.(5): Data processing flow chart

3. PROCESSING AND RESULTS

3.1. Field Geometry

The first step in seismic data processing is converting of raw data, which is in SEG-Y file format originally, to a format suitable with the Processing software setting. At this stage, information such as receivers, number of shots, minimum and maximum offsets, interval between receivers and equidistance of shot points are loaded into the inputted data (de Lucena Rêgo et al., 2017). The software uses the database to sort the traces and further complete the processing. Figure .6 shows the survey data after applying geometry. This step is necessary in seismic data processing in order to input the observer report values in form of FFID, XY coordinate data and station data so that the data is processed accurately with the actual field position. Figure.7 shows the XY graph of survey line.

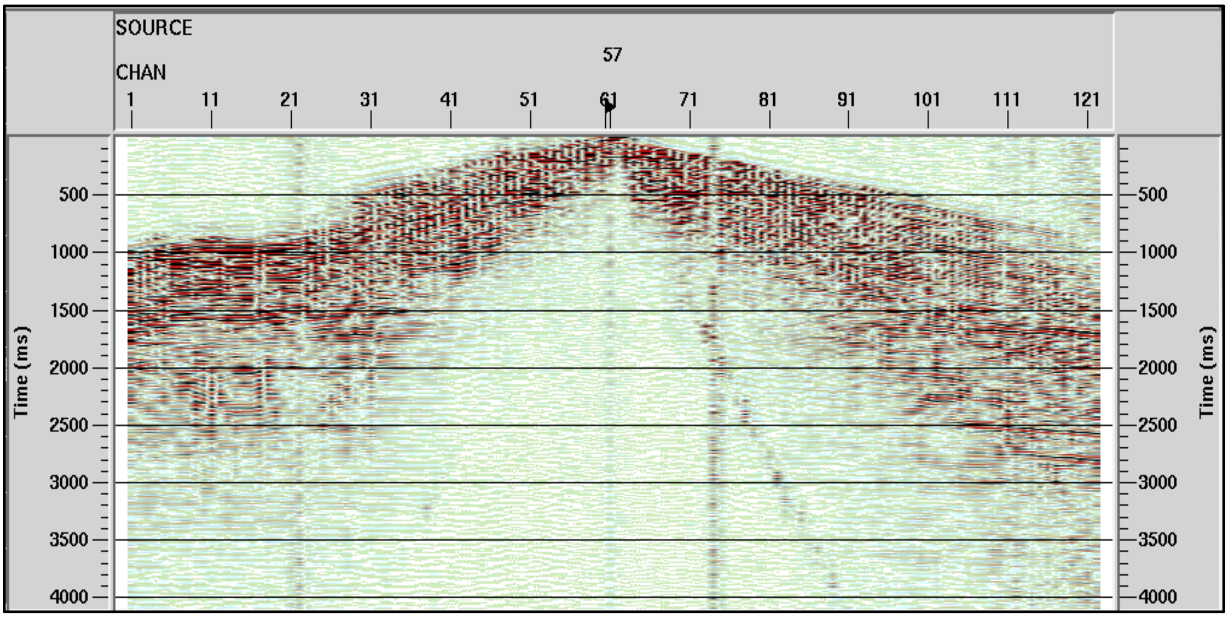

Fig. (6): Shot gather after Geometry application

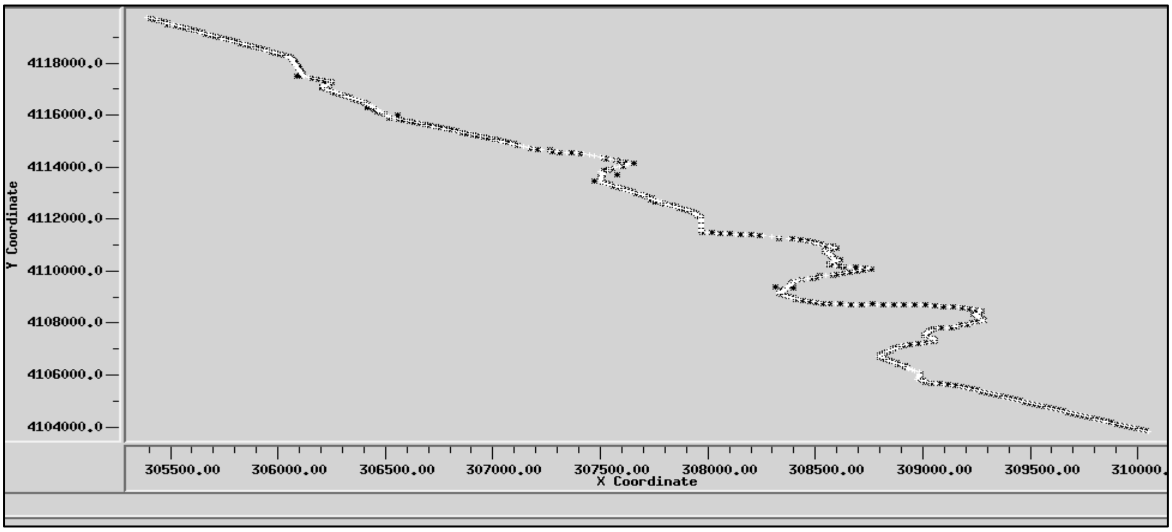

Fig.(7): Survey line XY graph between: Source (Black point) and Receivers (White points) after geometry application

3.2. Pre-Processing

There are many procedures at this stage. Because in seismic records there are low and high frequency noises which needed to be filtered, the Ormsby bandpass filter is used, the filter that operates with frequency domain by use of four frequency values. True Amplitude Recovery is applied to compensate the energy that lost due to geometric and spherical divergence, and absorption by adjusting the data amplitudes. Next, in static corrections, the effect of variation in elevation with source and receiver is removed, which is a theoretical shift of source and receivers to a specific datum (Mukhtar & Aswad, 2016).

This datum is where the velocity analysis and CDP stack are applied and is a smooth function of the elevation profile (Gavotti & Lawton, 2013).

The selected datum was 760 m and the replacement velocity was 3000 m/s. After static correction, noise attenuation is applied which removes unwanted signals from seismic data such as random noise. After the denoising process trace editing is applied which aims to kill and remove damaged trace data by applying specific trace statistics. Figure. 8 shows the shot gather before and after trace editing. The next step in processing was deconvolution which attempts to increase the temporal resolution of data by removing the seismic wavelet from the trace.

There are several types of deconvolution, predictive deconvolution is used in this research. This method attempts to estimate and eliminate predictable parts of the seismic trace (such as multiple reflections and ground roll signals) therefore, changes the input pulse shape (Figure. 9).

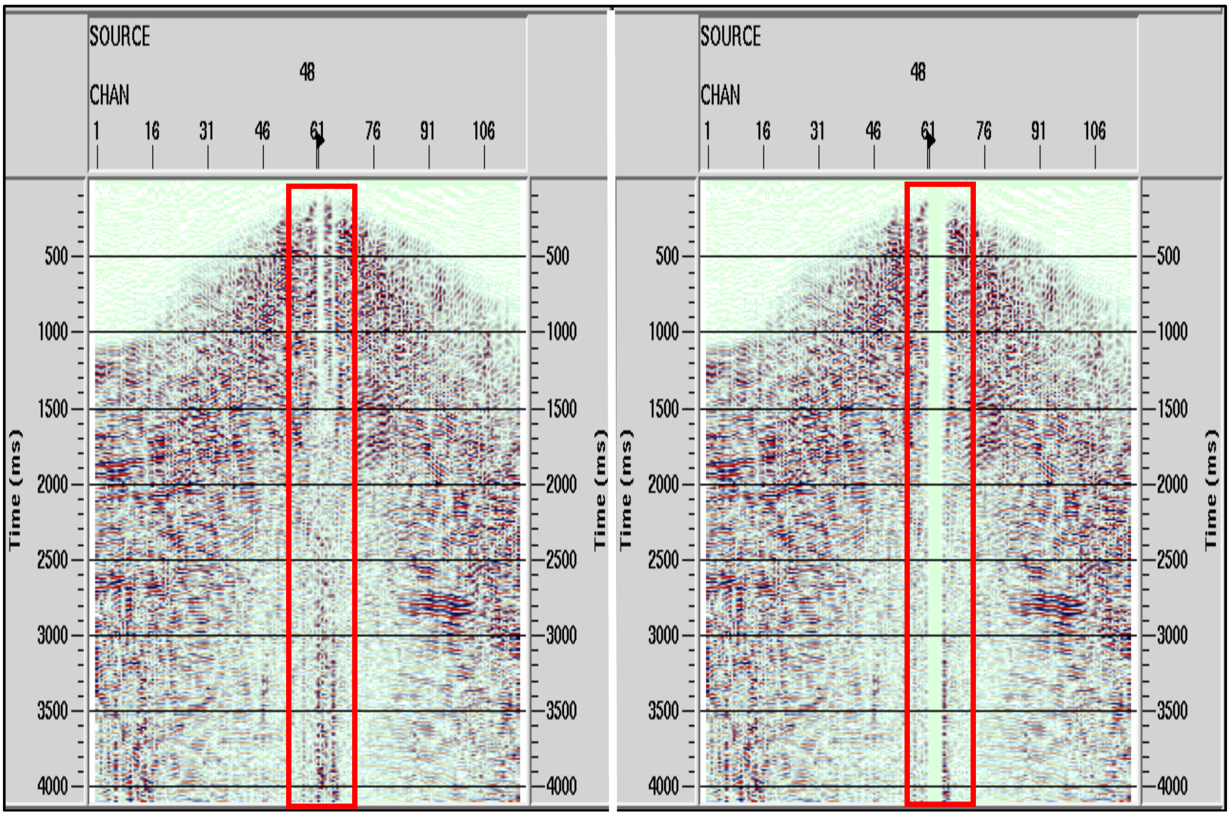

Fig.(8): Survey shot gather **A)** before , **B)** after trace editing

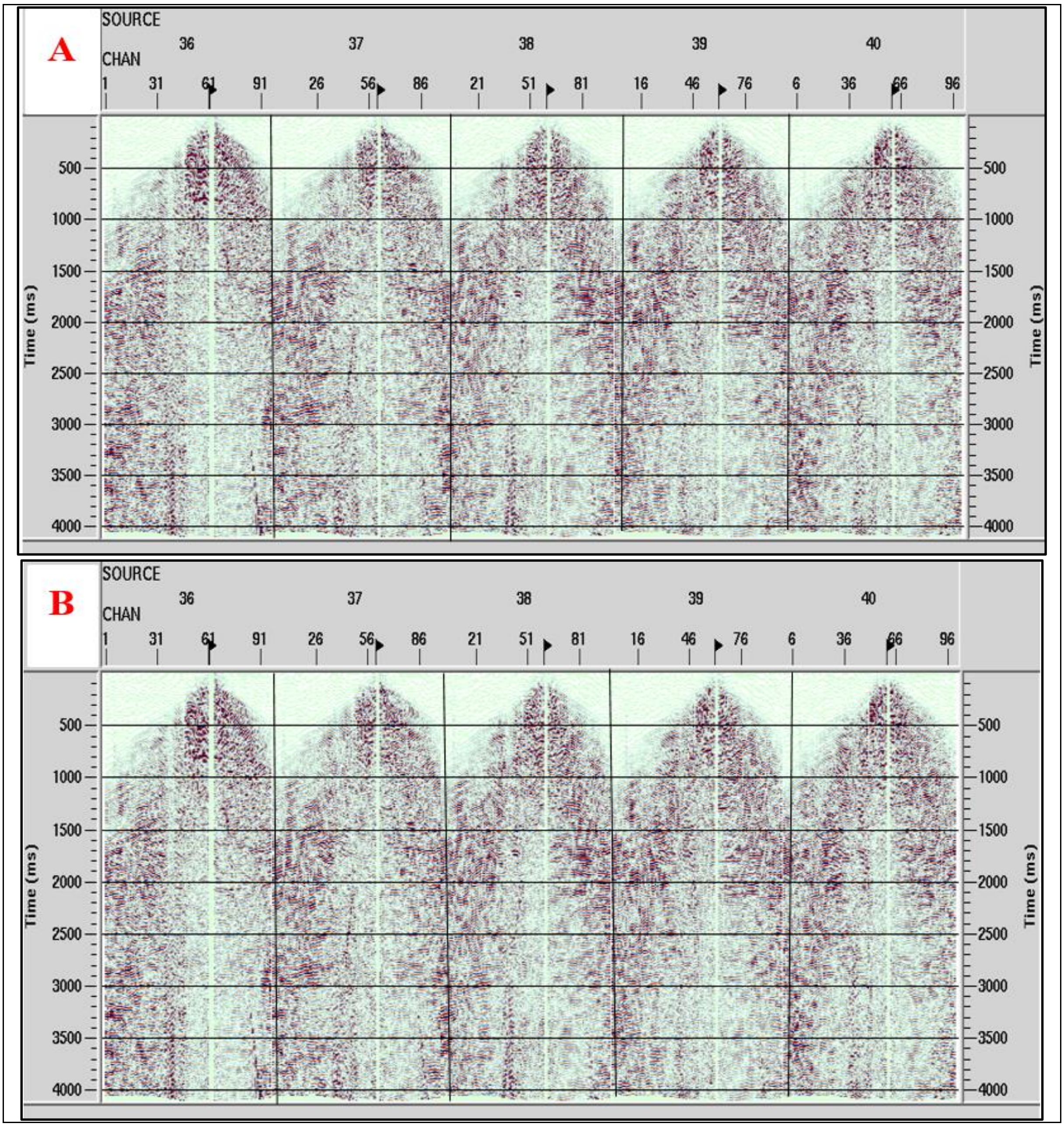

Fig.(9): The shot gathers **A)** Before , **B)** After applying predictive deconvolution

3.3. Velocity analysis, NMO Correction and Stacking

Velocity analysis is an interactive process used in seismic data processing in order to explain stacking (NMO) velocity or residual move out on pre-stack seismic section. NMO correction is the process of removing the effect of move out (far offsets) on travel times by making all traces zero-offset. The velocity analysis is performed by picking the velocity field interactively with using of semblance panel and velocity stacks that best modifies Common depth point (CDP) gathers (Gavotti & Lawton, 2013). Figure.10 shows the result of velocity analysis by a 2D velocity model and reflects the subsurface geologic settings. The objective of the velocity analysis, as previously noted, was to obtain a velocity field to which the NMO correction could be applied. Using the RMS velocity, this technique aims to align the events on CDP gathers. The seismic section is then created by stacking all of the traces. Figure.11 shows the seismic section after stacking.

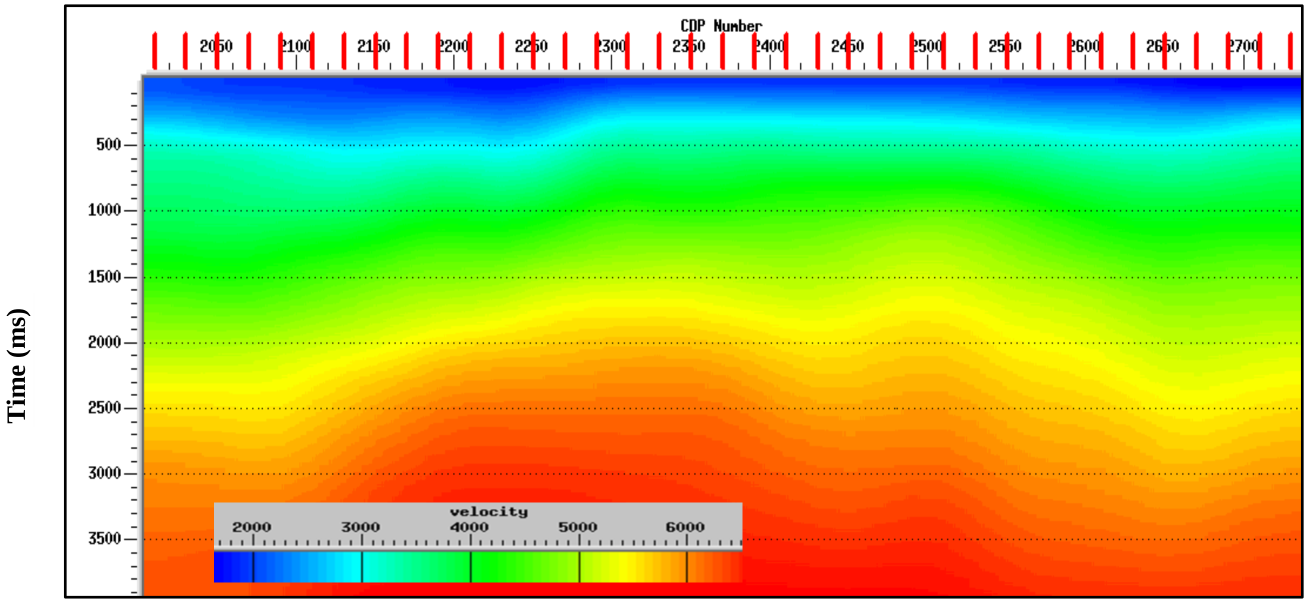

Fig.(10): 2D velocity model resulted from velocity analysis

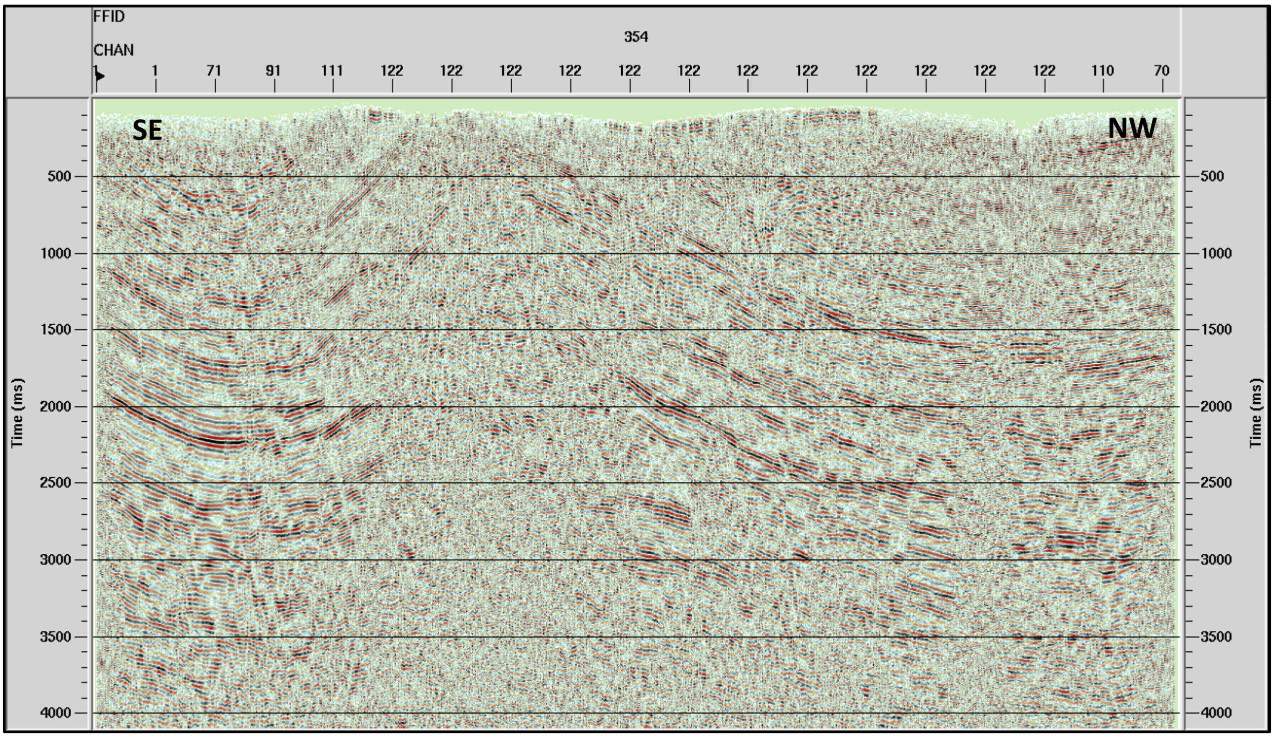

Fig.(11): Stacked seismic section after velocity analysis

3.4. Pre-stack and Post-stack time migration

The next step in processing and the core of this research is migration. In the migration process the reflections are moved to their actual subsurface position. Several migration methods have developed depending on the complexity of the geology and the features of the seismic data. In this study Kirchhoff algorithm is used for pre-stack and post-stack time migration by a tool used in software called “2D Prestack Time Migration” and “2D Poststack Time Migration”. For post-stack time migration, the parameters used are Migration aperture (1000-6000 m) and a maximum dip angle equal to 45°. Post-stack time migration section showed high improvement and resolution compared with the stacked seismic section before the migration process (Figure.11). In Pre-stack time migration, the same parameters are used with the only difference, that in pre-stack migration the offsetbin is applied in imaging, which is the type of data arranging method that depends on the offset unit of the investigation by subdividing the data to offset classes (Obaid et al., 2020). In other words, for Pre-STM individual traces were gathered in mutual offset groups. After migrating these groups, the data rearranged in CDP gathers to implement the process of stacking. For this reason, longer computing time is required for Pre-STM because of a larger number of seismic traces compared with Post-STM migration. Figure.13 shows the seismic section after applying pre-stack time migration.

4. DISCUSSION

Although the findings of each seismic survey depend entirely on the aims of the study, subsurface geological condition and the quality of data used by means of acquisition and processing the resulted seismic sections of this study were compared with the findings of related previous studies in order to evaluate the efficiency of both types of migration (pre and post-stack) in presenting an accurate subsurface image from 2D seismic data. Furthermore, for QC of migrated seismic section the seismic velocity has been updated for obtaining more accurate migrated section and the velocity model is shown in Figure 14. The figures (15 and 16) show the resulted migrated section after updating of velocity.

The results showed that, The Pre-stack time migrated section (Figure.16), shows more accurate subsurface image with greater resolution comparing to (Figure.15) .Furthermore, the dipping events moved to their actual location and the diffractions collapsed, therefore the location of faults clearly appeared on the migrated section (red lines).

With the obvious improvement of resulted images during all processing stages, the results lead to similar decisions that stated that:

First, in Migration of seismic data in order to find the correct position of CDP, accurate velocity is most crucial parameter.

Second, the seismic sections that migrated with Pre-stack migrations demonstrate better subsurface images of areas with complex geology (red boxes in figures 15 and 16).

Third, the same seismic sections (subsurface images) will provided, if the migration applied on seismic sections with simple subsurface geology and low variations in lateral velocity, In other words, with horizontally layered subsurface and simple velocity, there cannot be considerable difference between pre or post-stack time migrated section.

Furthermore, an acquisition parameters such as fold coverage, the length of survey line and source and receiver spacing (offset) are the key parameters for obtaining a seismic section with high signal strength (S/N) after the process of stacking.

Additionally, each processing stage is applied by utilizing different parameters and testing their effect in order to select the most accurate result at each stage. This resulted a subsurface image with better signal to noise ratio (S/N) in both the migrated and unmigrated seismic sections.

5. CONCLUSION

The processing of 2D raw seismic data is performed with focusing on migration, which is a processing stage that deals with the imaging phase of seismic data processing. Seismic datasets undergo several processing stages in order to create an accurate subsurface image. Migration can be applied in two methods, before and after the processes of CMP stacking. Both methods are applied pre-stack and post-stack time migration. Regarding the results, pre-stack migration was more reasonable than post-stack migration and presented a seismic image with higher resolution. However, after applying more gains and filters, both methods created an adequate seismic section that shows more promising subsurface settings

Finally, it is necessary to mention that the results of each seismic processing work depend entirely on the geological complexity and the velocity variation of the studied area.

Moreover, the amount of noise S/N contained in data depending on the acquisition stage of data, the processing workflow and the purpose of the study.

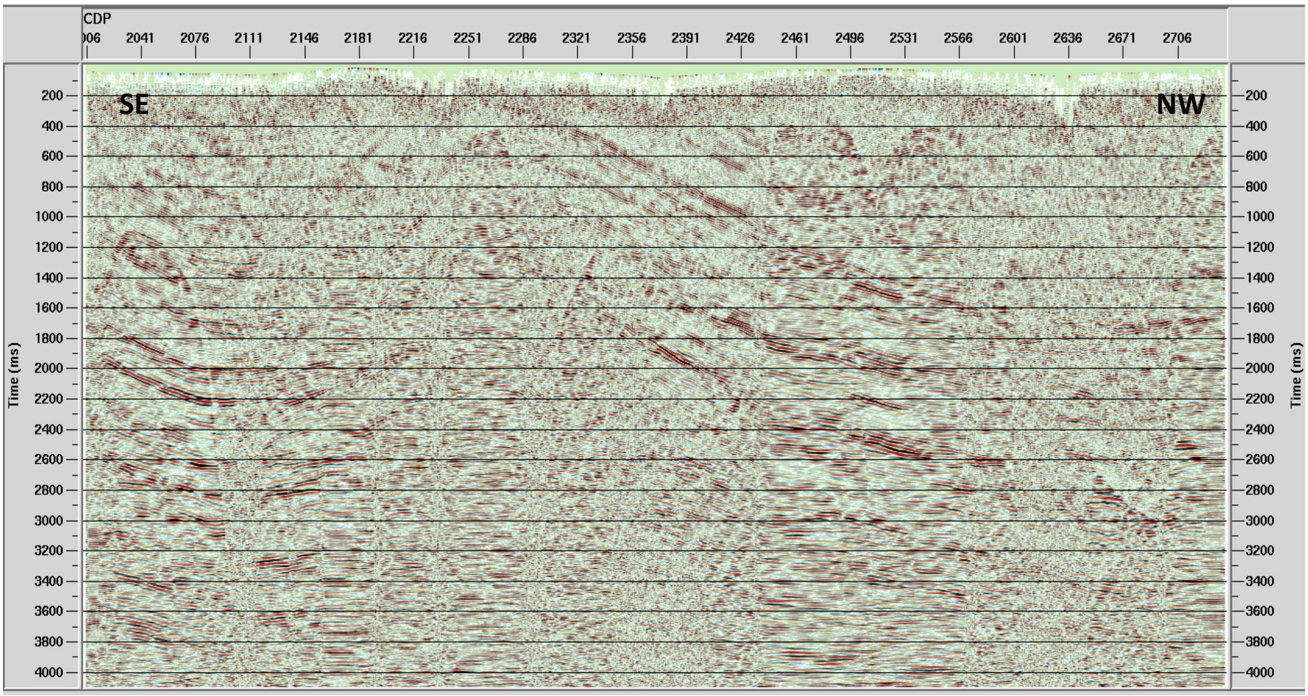

Fig.(12): Seismic section after post-stack time migration applying

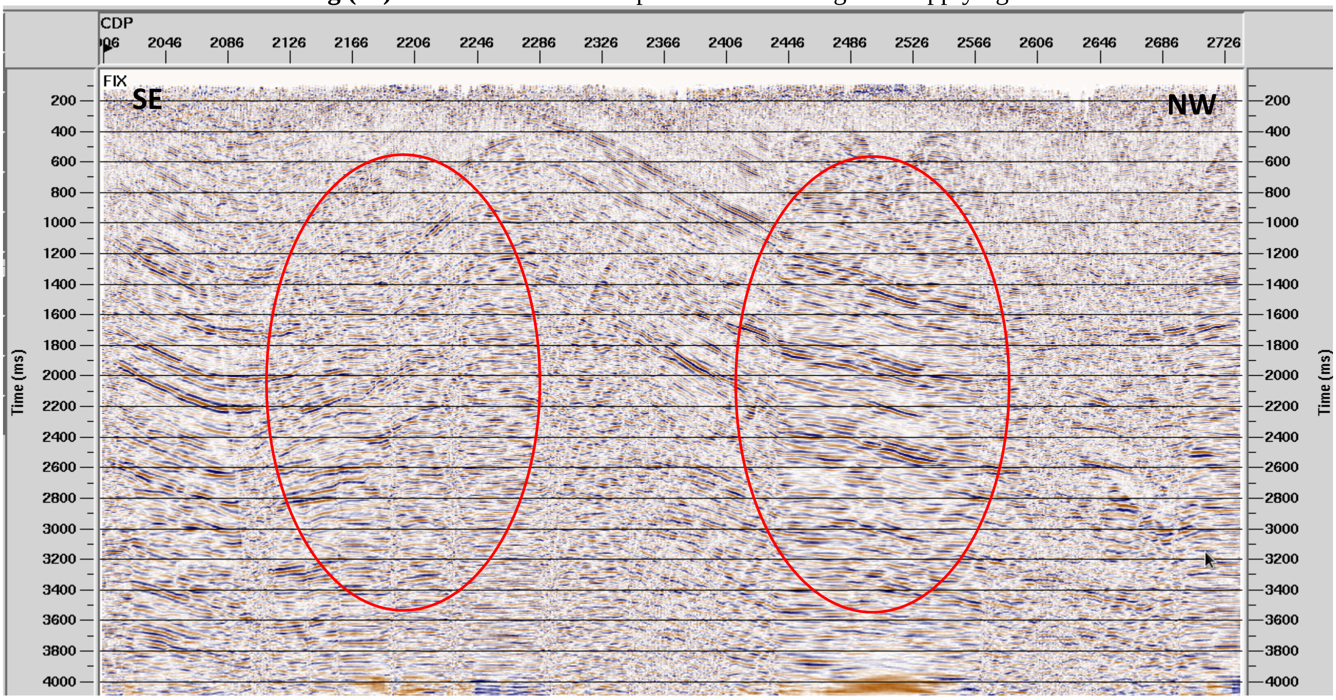

Fig.(13): Seismic section after pre-stack time migration applying

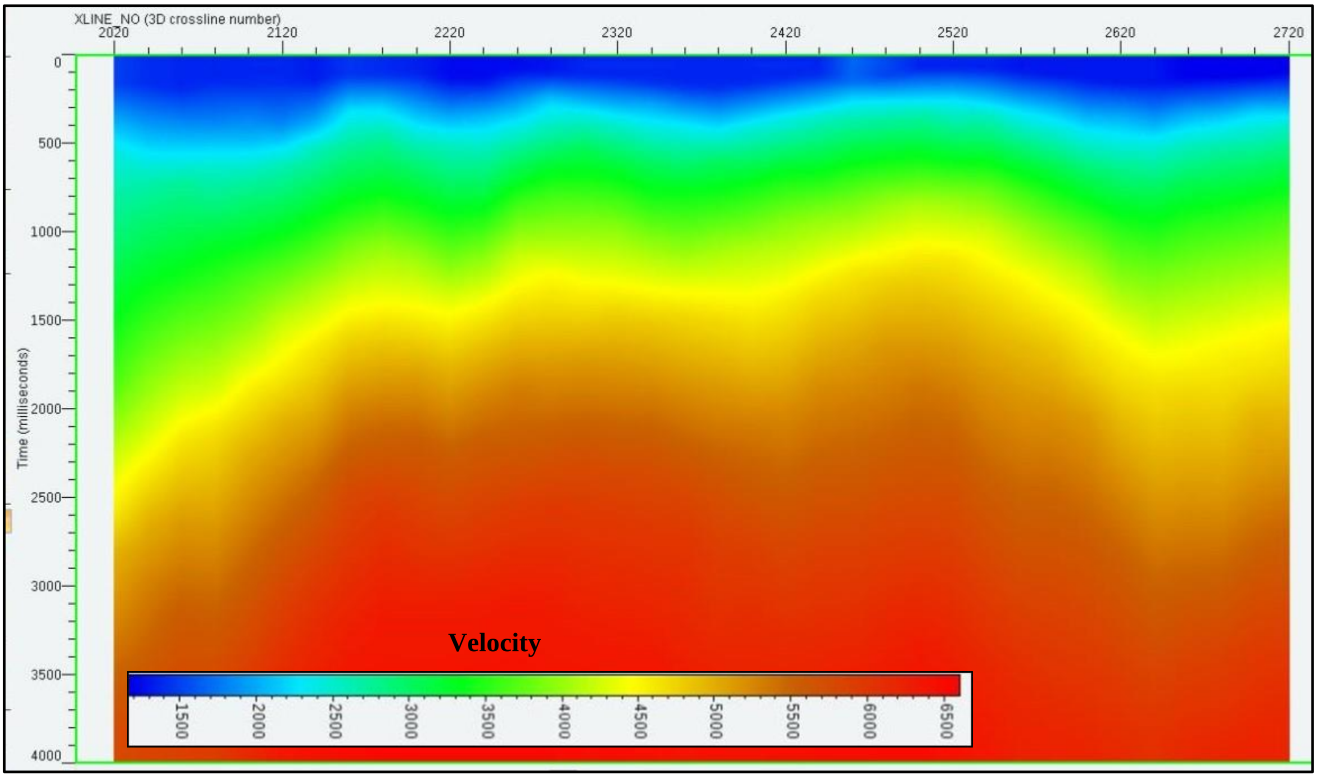

Fig. (14): Velocity model after update with (KTMIG)

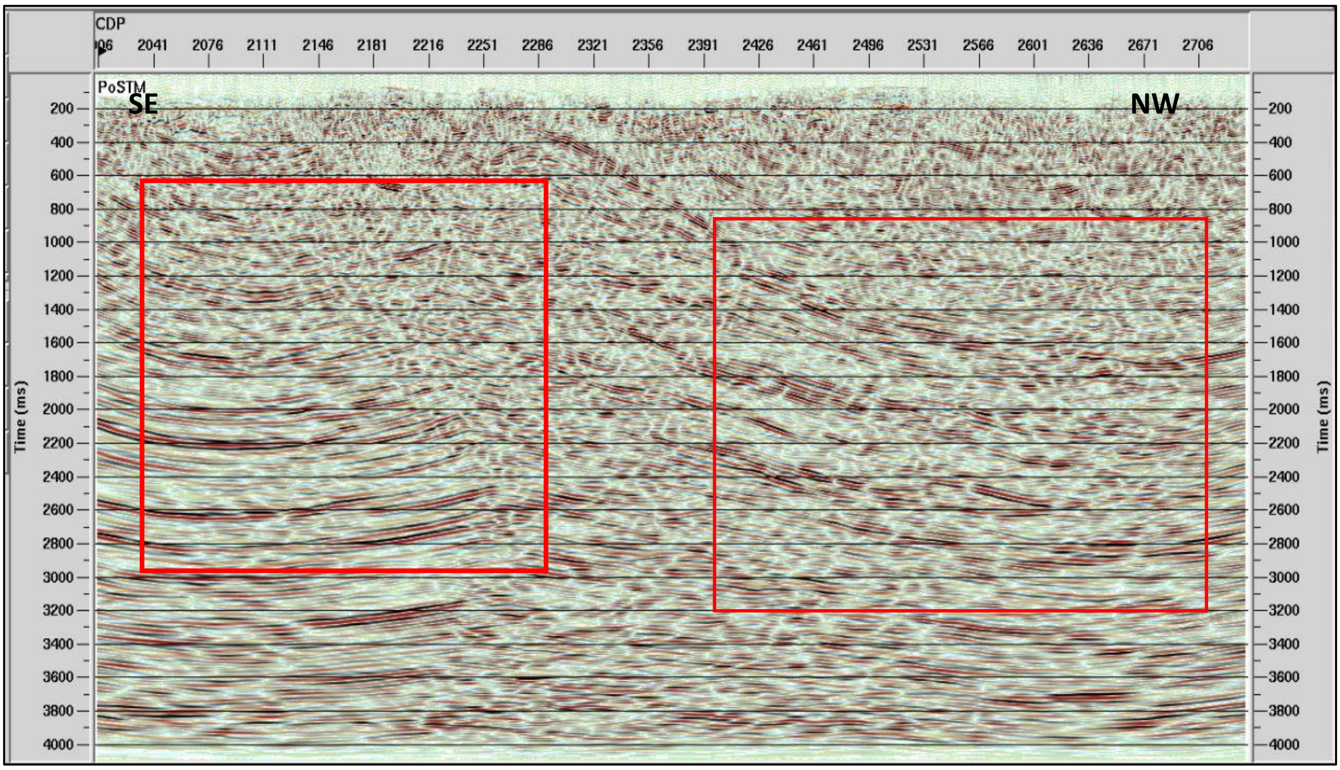

Fig.(15): Post-stack time migration after velocity re-picking

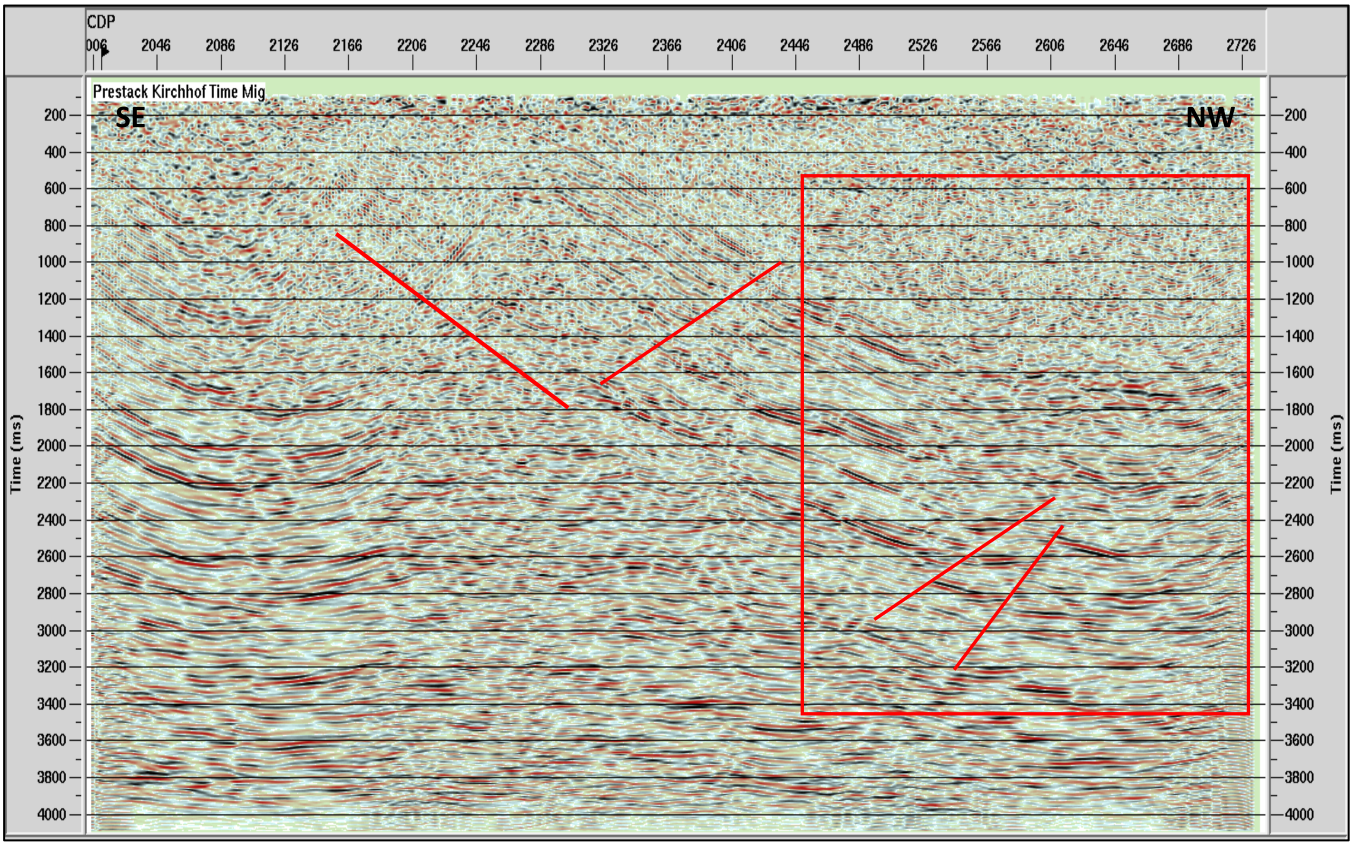

Fig.(16): Pre-stack time migration after velocity re-picking

6. REFERENCES

AL-Moadhen, A. A. (2009). Regional structural study of Ga'ara area in western desert of Iraq using Landsat image data, unpublished MSc. Thesis, university of Baghdad,Iraq.

Al-Mosawi, H. A. S.,(2007). The geology of ZAKHO quadrangle sheet NH –38 – 9 Scale 1:250,000. GEOSURV, Int. Rep. No. 3110, Baghdad, Iraq.

Al Sadi, H. N., & Baban, E. n. (2020). Introduction to seismic exploration. In University of Sulaimani (First, Issue June). https://doi.org/10.1007/978-3-030-32948-8_1

Bamerni, A., Al-Qayim, B., Hammoudi, R. A., & Frontalini, F. (2021). High-resolution biostratigraphic analysis of the Cretaceous-Paleogene Boundary in the Kurdistan Region (NWIraq). Stratigraphy, 18(4), 251–268. https://doi.org/10.29041/strat.18.4.02

Bancroft, J. c. (2007). A practical understanding of pre- and post stack migrations. In SOCIETY OF EXPLORATION GEOPHYSICISTS (2007 editi, Vol. 1).

Bednar, J. B. (1999). A theoretical comparison of equivalent-offset migration and dip moveout-prestack imaging. Society of Exploration Geophysicists, 64(1), 13–310.

de Lucena Rêgo, R. C., de Lima Neto, O. A., & da Silva, C. C. N. (2017). Conventional seismic processing flow analysis: 2D line of the Rio Grande Chain region Southeastern Brazil. SBGf, 1507–1512. https://doi.org/10.1190/sbgf2017-294

Deregowski, S. M. (1986). What is DMO? First Break, 5, 7–24. https://doi.org/10.3997/1365-2397.1986014

Dondurur, D. (2018). Acquisition and Processing of Marine Seismic Data. Elsevier.

Gavotti, P. E., & Lawton, D. C. (2013). Seismic processing for coherent noise suppression Seismic processing workflow for supressing coherent noise while retaining low-frequency signal. CREWES Research Report, 25, 1.

Guo, J., & Young, J. (2004). Complex structural velocity model building for depth imaging. Journal of Geophysics and Engineering, 1(3), 216. https://doi.org/10.1088/1742-2132/1/3/006

Hale, D. (1984). Dip-moveout by Fourier transform. Society of Exploration Geophysicists, 49(6), 686–847. https://doi.org/10.1190/1.1441702

Jassim, S. Z., & Goff, J. C. (2006). The Geology of Iraq. Dolin, Hlavni 2732 , Moravian Museum, Zelny trh 6.

Landmark. (2013). SeisSpace® ProMAX® Software Family. l. https://www.halliburton.com

Mamaseni, W. J., Naqshabandi, S. F., & Al-Jaboury, F. K. (2019). Palynofacies And Paleoenvironment of Late Jurassic-Early Cretaceous Formations at Duhok. Iraqi Geological Journal, 52(1), 61–82.

Mukhtar, K. S. Al, & Aswad, N. N. (2016). Application of the Elevation and Residual Static Correction methods on a selected Seismic data of West Luhais area in the South of Iraq. 57(1), 651–662.

Obaid, F. A., Al-Rahim, A. M., & Ali, H. Z. (2020). Subsurface imaging of 2d seismic data using kirchhoff time migration method, central Iraq. Iraqi Journal of Science, 61(12), 3318–3326. https://doi.org/10.24996/ijs.2020.61.12.19

Reiner, F. P. (2018). Deconvolution of Seismic data from mine production blasts. MSc. Thesis, University of Montan,1-93

Ristow, D., Hinz, K., Hauschild, J., Gindler, T., Berhorst, A., & Bönnemann, C. (2002). Imaging the Subsurface with 2-D and 3-D Seismic Data. Ocean Margin Systems, 33–55. https://doi.org/10.1007/978-3-662-05127-6_3

Shiya, Y. F. (2021). Updating the 2D Seismic data by pre-stack Depth Migration of Khashim Al-Ahmer Gas Field, Northeasteren Iraq. University of Baghdad.

Sissakian, V. K., (1995). The geology of ZAKHO quadrangle sheet NH –38 – 9 Scale 1:250,000. GEOSURV, Int. Rep. No. 3110, Baghdad, Iraq.

Smitha, N., Ullas Bharadwaj, D. R., Abilash, S., Sridhara, S. N., & Singh, V. (2016). Kirchhoff and F-K migration to focus ground penetrating radar images. International Journal of Geo-Engineering, 7(1). https://doi.org/10.1186/s40703-016-0019-6

Veeken, P. C. ., & Moerkerken, B. Van. (2013). Seismic Stratigraphy and Depositional Facies Models. EAGE Publications.

Yilmaz, Ö., & Claerbout, J. F. (1980). Prestack partial migration. Society of Exploration Geophysicists, 45(12), 1741–1883

Yousefzadeh, A. (2013). High Resolution Seismic Imaging using Least Squares Migration [University of Calgary]. https://doi.org/10.11575/PRISM/26363

Zhang, K., Cheng, J., Ma, Z., & Zhang, W. (2006). Pre-stack time migration and velocity analysis methods with common scatter-point gathers. Journal of Geophysics and Engineering, 3(3), 283–289.https://doi.org/10.1088/1742-2132/3/3/010

Zhang, M., Li, X., & Wang, M. (2004). Finite-element implementation of reverse-time migration for anisotropic media. Journal of Geophysics and Engineering, 1(2), 103–108. https://doi.org/10.1088/1742-2132/1/2/001

وێنەگرتنا ژێرزەڤی یا زانیاریێن پیڤە لەرزەی یّن دوو ڕویی 2D بریّکا کوچکرنا وەختی بەری کومکرنێ وپشتی کومکرنێ، هەریما کوردستانا عیراقێ

پوخته

بەشێن پیڤەلەرزێ یّن دەڤەرین خودان جیولوجیەکا ژێر زەڤی یا ئالوز بویەرێن جودا جودا پێشان ددەن، نموونا پرت و بەرەلابونا شەپولا ،نە بەردەوامیا ریێ رەنگڤەدانێ و ژمارەیەکا زور یا سیگنالێن بی مفا دگەل داتایێن سەرەکی، ژ ئەگەرێ ڤێ چەندێ شروڤەکرنا ڤان جورە وێنا یا ئالوزە و د شیانێن شروڤەکاری دا نینە کو وەسفەکا راست و دروست یان زانیاریێت باوەرپێکری یێن دەڤەرێ بدەت. ئارمانج ژ ڤێ تویژینێ پروسێسکرنا هێلەکا دوو ڕویی (2D) ژ داتایێن رەنگڤەدانا پەڤەلەرزی یّن دەڤەرەکا هەرێما کوردستانا عێراقێ یە برێکا پروگرامێ پروسێسکرنا داتایێن پیڤەلەرزا .روتینێ پروسێسکرنێ پێکهاتی ژ دوو بەشان هاتە بکارئینان ئەو ژی، کوچکرنا وەختی یا بەری کومکرنێ **(Pre-stack time Migration)** و پاش کومکرنێ **(Post-stack time Migration)**.پارامیتەرێن جودا جودا هاتنە تاقیکرن ب مەبەستا بەراوردکرنێ و هەلسەنگاندنا کارا یا وان د باشترکرنا داتایان دا.ئەنجامان دیارکر وێنێ بدەستڤەهاتی ژ ئەگەرێ کوچکرنا پشتی کومکرنێ پێشڤەچوونەکا بەرچاڤ پێشان ددەت بەراوردی دگەل وێنێ کومکری بێ کوچکرن.بەلێ وێنێ هاتییە چارەسەرکرن ب کوچکرنا وەختی یا بەری کومکرنێ هەرەباشترین وێنێ ژێرزەڤی پێشان دا.

تصوير تحت السطح للبيانات السيزمية ثنائية الأبعاد 2D باستخدام التهجير الزمني قبل وبعد التنضيد، إقليم كردستان العراق

الخلاصة

تشمل المقاطع الزلزالية للمناطق ذات الجيولوجيا تحت السطحية المعقدة أحداثًا مختلفة مثل الانحرافات وموضع العاكسات غير الدقيقة والسعات الزلزالية غير المؤكدة وبالتالي فإن المفسر غير قادر على اعطاء التفسير الدقيق و صعوبة في تحديد الجيولوجيا تحت السطحية من الصورة الزلزالية. لذلك من أجل إنشاء صورة دقيقة وتوضيحية لتحت السطح ، هدفت هذه الدراسة إلى معالجة سطر واحد من بيانات الانعكاس الخام ثنائية الأبعاد ، من إقليم كردستان ، شمال العراق ، باستخدام برنامج معالجة البيانات الزلزالية. يتم تطبيق تدفق المعالجة الذي يتكون من إجراءين ، وهما ترحيل الزمني ما قبل التنضيد وبعده. تم اختبار المعلمات المختلفة في جميع مراحل المعالجة من أجل مقارنة وتقييم كفاءتها في تحسين البيانات الزلزالية. أظهرت النتائج أن الصورة التي تم ترحيلها في فترة ما بعد التنضيد أظهرت تحسنًا كبيرًا في الصورة تحت السطحية مقارنةً بالقسم المكدس دون الترحيل. في حين أن ترحيل الزمني ما قبل التنضيد قدم صورة أفضل لتحت السطح.