



SIMULATING PRE AND POST STACK MIGRATION FOR 2D SEISMIC LINE IN BALAD-SAMARRA AREA, CENTRAL IRAQ: A SEISMIC UNIX IMPLEMENTATION

¹Ali M. Al-Rahim and ²Fadhil Abdulabass Obaid*

¹Department of Geology, College of Science, University of Baghdad. Baghdad, Iraq

²Department of Geology, College of Science, University of Baghdad. Baghdad, Iraq

*E-mail: abualwleed.fadhil@gmail.com

Received: 22 June 2019; accepted: 29 July 2019

ABSTRACT

Migration is a process by which reflectors are re-positioned to their true subsurface locations. The accuracy of the migrated velocity model and time determines the subsurface imaging quality. For complex structures, the reflecting and/or diffracting energy from source points will not vertically be oriented beneath the common mid-point (CMP). However, an acceptable migrated velocity model is usually performed by several parameters. Stolt migration method is applied to a 2D seismic line within Salah Al-Din province (Balad-Samarra area), central Iraq. To understand the effect of Stolt migration method and parameters used in the migration, a simulated synthetic model has been made with the same field parameters for the studied seismic line and with the same vertical cross-section of the geological subsurface layers. This model is constructed to generate raw seismic data, which was reprocessed using Seismic UNIX (SU) package in the post and pre-stack migration situation. Stolt migration is applied in the time domain for the modeled processed data to test the effects of changing the values of each parameter. A suitable migrated velocity values deduced from the analyzed model is tested for real surveyed line and the images results for the subsurface structures are accurate without diffraction. The results indicate that pre-stack time migration is best due to the lateral velocity variation and structural complexity and velocity analysis confirm that pre-stack is better than post-stack time migration.

Keywords: Seismic unix; Stolt migration; Post-Stack time migration; Pre-Stack time migration

INTRODUCTION

Seismic imaging techniques are accustomed to produce an image, or section, that equivalent the geological structure in the subsurface. Migration is a term that used in seismic reflection survey which is defined as moving the dipping reflectors events to their true subsurface positions and decreases the diffractions (Gardner, 1985), thus increasing spatial resolution, as well as increase the signal-to-noise ratio on the time sections and, at the same time, provide a velocity distribution profile of the geological subsurface will create a perfect seismic image of the subsurface (Gray et al., 2001). Due to the source and receiver are sets on the ground as Omni-directional, the reflecting or diffracting energy from source points will not vertically beneath the common mid-point (CMP), which it can be ambiguous to the interpretations, here, the migration will be applied to reposition the subsurface structural events to their true position (Fehler and Huang, 2002). Migration principle is Huygens's secondary source principle. This is a state that any point on a wave front can be as a secondary source which is producing circular wave fronts when viewed as two dimensions. The process of migration is to collapse the apparent secondary wave fronts to their points of origin. (Reynolds, 1997).

In a complex geological structure with high dips, the migration process needs to test several parameters to get the final reasonable geological image. The 2D seismic section of Ajeel field Balad-Samarra (BS-92) along a seismic line, which is located in Salah Al-Din province, between Balad-Samarra area, central Iraq, reveals bad data and complex geological structure. In this work, a simulated synthetic model is constructed for the same field with the same parameters that are used to acquire BS-92 line in the Iraqi Oil Exploration Company. The simulated model is constructed to get raw seismic data and processed to get the final stacked section. Later on, a Stolt migration method was tested to endeavor the geological image. All simulation, acquiring raw data, processing and migration is implemented using Seismic Unix which is an open-source seismic utility package that was supported by the Center for Wave Phenomena (CWP) at the Colorado School of Mines (CSM).

THEORETICAL BACKGROUND

Stolt migration method, also called (F–K) Direct Fourier Transform Migration. It was presented by Stolt in 1978. The term (F – K) is derived from the Fourier transform of time to frequency(F), and distance to wave-number(K). This method is idyllic when the velocity is constant for all the stack section and provides correctly migrated section up ninety degrees (Stolt, 1978).

Stolt described his method mathematically as think through the earth to be a two-dimensional, half-space and assume sound travel as a scalar field with a velocity at point (X, Z) of $C(X, Z)$. Each point in the earth has the facility to transform down-going sound waves into up-going sound waves this property is characterized by reflection strength $[R(X, Z)]$, (Fig.1) (Stolt, 1985; Claerbout, 1971). The mathematical details are left and the final equation is (Yilmaz, 2001):

$$P(K_X, K_Z, t = 0) = \left[\frac{v}{2} \frac{K_Z}{\sqrt{K_Y^2 + K_Z^2}} \right], \quad P \left[K_X, 0, \omega = \frac{v}{2} \sqrt{K_Y^2 + K_Z^2} \right], \quad \omega = \frac{v}{2} \sqrt{K_Y^2 + K_Z^2}$$

The output of the Stolt migrated is scaled and defined by the quantity (S) as follow:

$$S = \frac{v}{2} \frac{K_Z}{\sqrt{K_X^2 + K_Z^2}}$$

Where $P(K_X, Z = 0, \omega)$ is the zero-offset section, $P(K_X, K_Z, t = 0)$ is the migrated section in the (F – K) domain, (K_X) is the vertical wavenumber and (ω) is the temporal frequency.

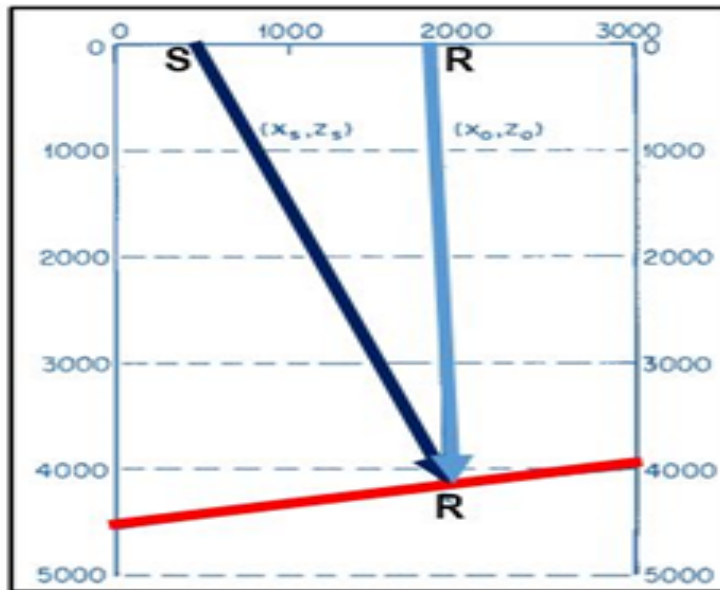


Fig. 1: Migration may be observed as a prediction of alterations in the seismic field as sources and receivers' locations are moved into the earth. With reverence to small changes in receiver or source location (Stolt, 1978)

The horizontal direction of (F – K) algorithms has restricted the ability in processing velocity variations. Stolt method includes the coordinate transformation from frequency to vertical wavenumber axis (K – X), while the horizontal axis of the wavenumber is kept without any adjustment. Stolt improved his method by presenting expansibility in the time direction to handle the forms of velocity variations for which time migration is suitable to combine theory with practice in the field of migration with an assurance on the frequency-wavenumber methods (Yilmaz, 2001; Stolt and Wegleint 1978). A time-domain section can be transformed to the frequency domain to yield the corresponding (F – K) plane. In the process, all dip components having a common angle on the time domain seismic section are consolidated into a single dip vector in the frequency domain (Lindseth and Geoph, 1982; Forel et al., 2005; Bleistein et al., 2013; Lorenzo, 2018; Prado et al., 2019).

STUDY AREA AND DATA AVAILABILITY

2D BS-92 seismic survey (Fig. 2), which is belongs to the 2D seismic survey project, was conducted by the Iraqi Oil Exploration during the years (1981–1986).

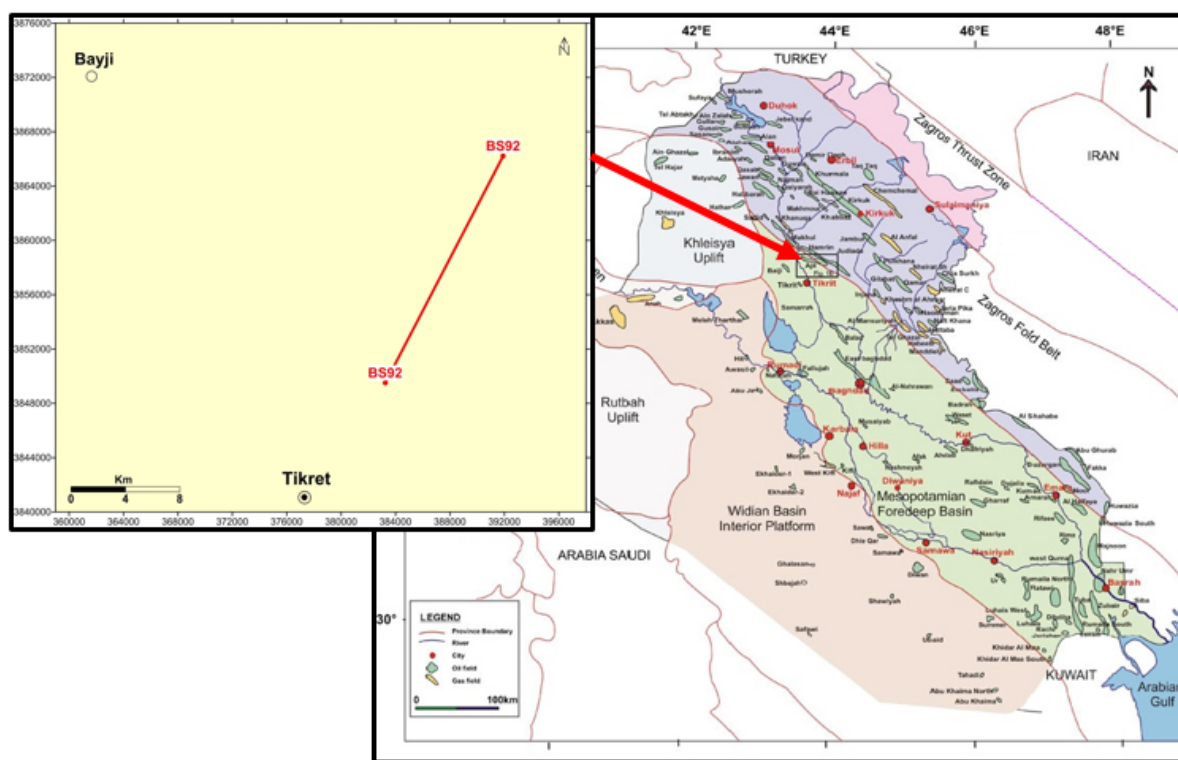


Fig. 2: Location of BS-92 survey line (Al-Ameri et al., 2013)

According to the divisions of Iraqi tectonic regime, the study area lies on the slope of the nearby the platform flank of the Mesopotamian basin. That is restricted by central faulted zone from north-east part and by the slope of the Afro-Arabian Platform from the southwest part, and is limited in the midst of the two main transversal faults, the first one is Sirwan transversal fault in the south, and the second one is Amij-Samarra Transversal Fault in the north of Samarra (Jassim and Goff, 2006). Historically, the area was influenced by extension deformations and tectonic tension over the Arabian Plate during Permian/Triassic–Lower Cretaceous, resulting in fractures and dislocation in the basement rocks. The differential gravitation forces occurred during the Triassic–Cretaceous ages caused the emergence of deep normal faults. Consequently, the normal faults extend north–south and northwest–southeast trends, the strike-slip faults extend east–west and northwest–southeast trends (Aqrawi et al., 2010).

BS-92 line has been reprocessing using Seismic Unix software package. The seismic processing subdivided into three substantial stages which are; data reduction, geometrical correction, data improvement and finally imaging process. Seismic Unix is implemented to simulation BS-92 seismic line; and these includes: creating synthetic model that is fits the actual reflectors of the section, static corrections, gain applications, noise attenuation, deconvolution, common mid-point (CMP) gathering, normal-moveout correction (NMO), dip moveout correction (DMO), velocity analysis, residual statics, stacking and imaging which are 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 Stolt migration method, many parameters should be fixed and applied on all the seismic section which are; distance between CMP, number of CDPs, migrated time, migrated velocity and target depth.

DATA PROCESSING AND RESULTS

Fig. 3A shows the actual section of BS-92 seismic line. The geological structure of the Ajeel field is not clear. Fig. 3B) shows the simulated synthetic model of BS-92 line. The acquired raw data from this model is implemented from applying trimodal program (one of seismic Unix programs package) that is dealing with the horizontal, vertical distance and the Root-Mean Square (RMS) velocity for each point in the surface of reflectors within a section.

The parameters, which was used to acquire the simulated model, for BS-92 line are: 240 source positions, where shots are equally spaced at 50 m intervals, 60 split-spread traces are recorded from each shot location with receiver spacing of 50 m, receiver offsets range from

0.0252 m to 15.475 m, shot locations range from 2 km to 14 km, geophone locations range from 0.525 km to 15.425 km. The final data set has 14,400 traces (Fig. 4), 240 shots x 60 geophones per shot.

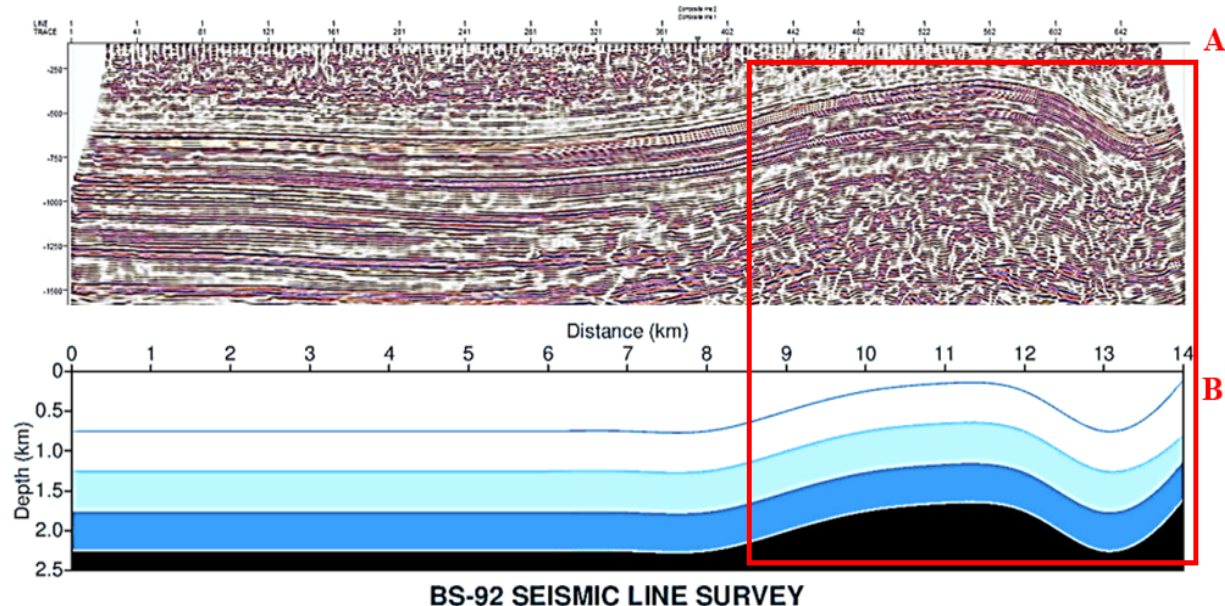


Fig. 3: (A) The actual section. (B) the simulated synthetic model

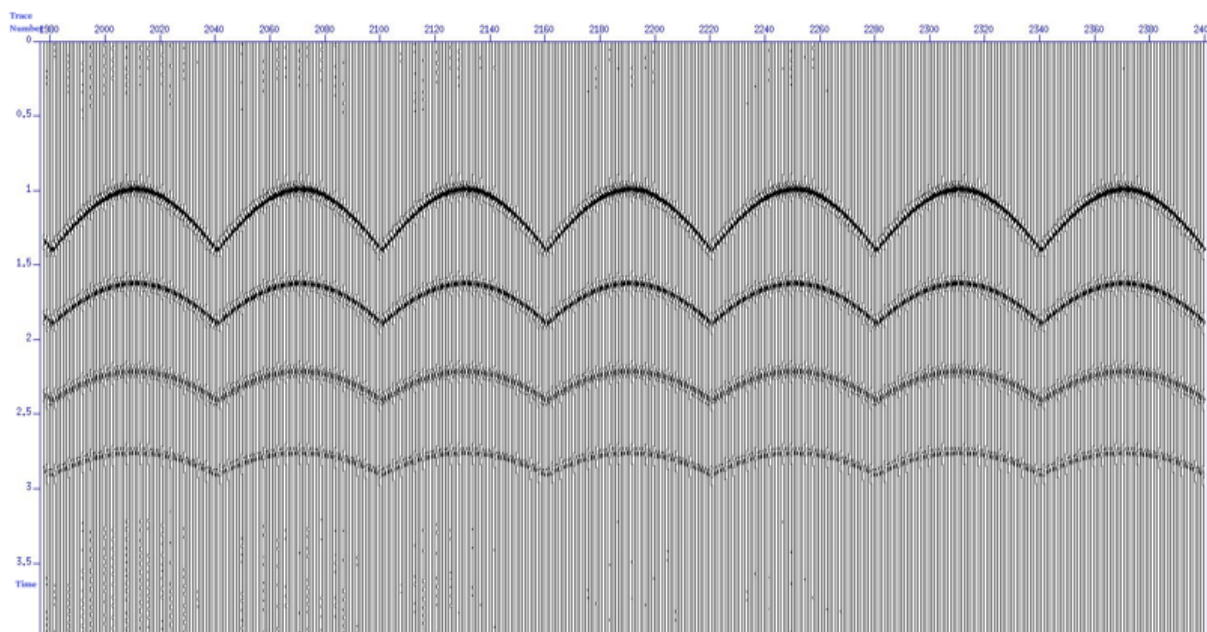


Fig. 4: Part of the raw seismic data from acquiring the simulated model

The second processing steps are sort shot gather data to CDP gather (Fig. 5), and NMO correction (Figs. 6 and 7).

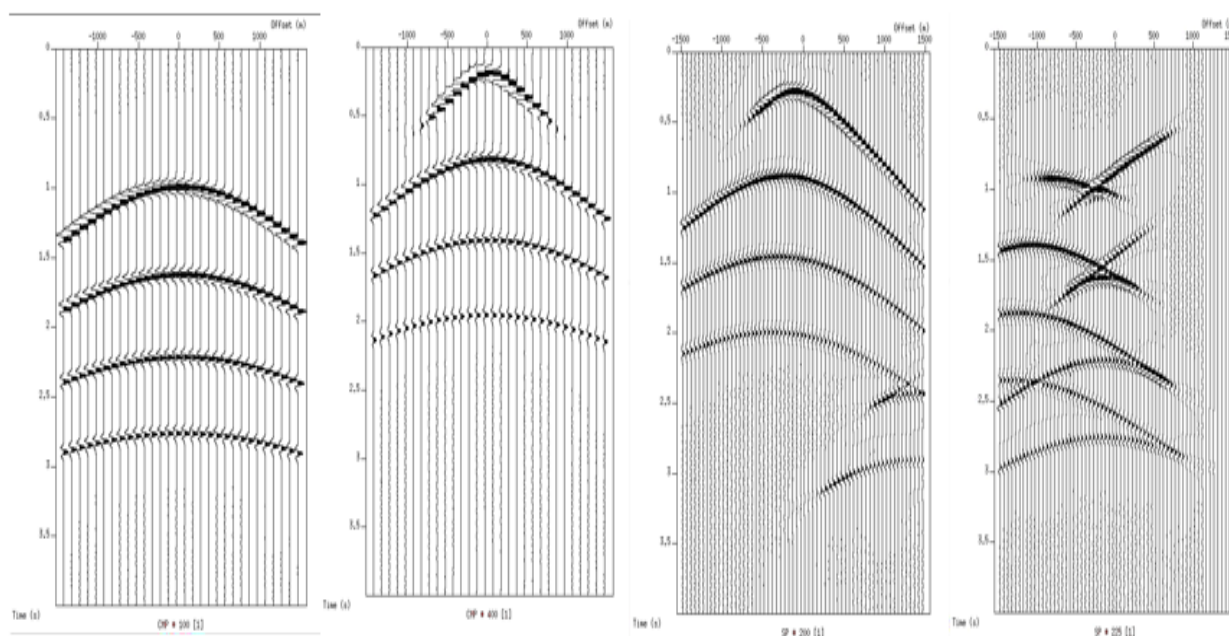


Fig. 5: Several CDPs of seismic data gaining

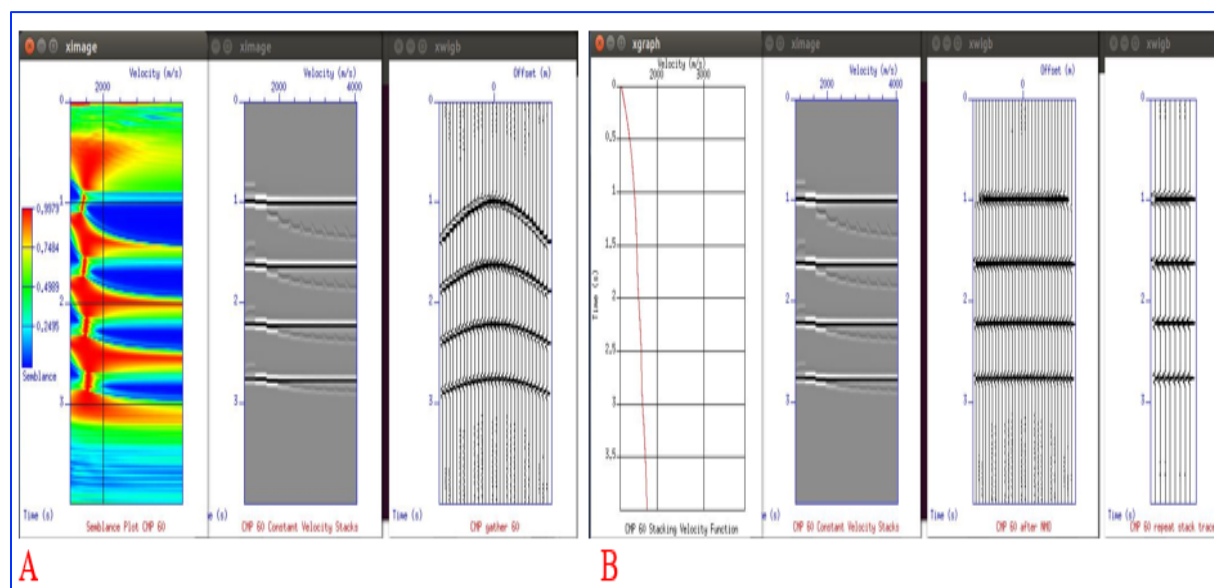


Fig. 6: The picked velocity semblance of NMO correction

(A) Before correction. (B) After correction

The final step in processing sequence is stacking the seismic section (Fig.8). The final results show the Bow-tie effect in the syncline part of the model which has to be corrected using Stolt migration to re-position the reflectors to their true subsurface locations.

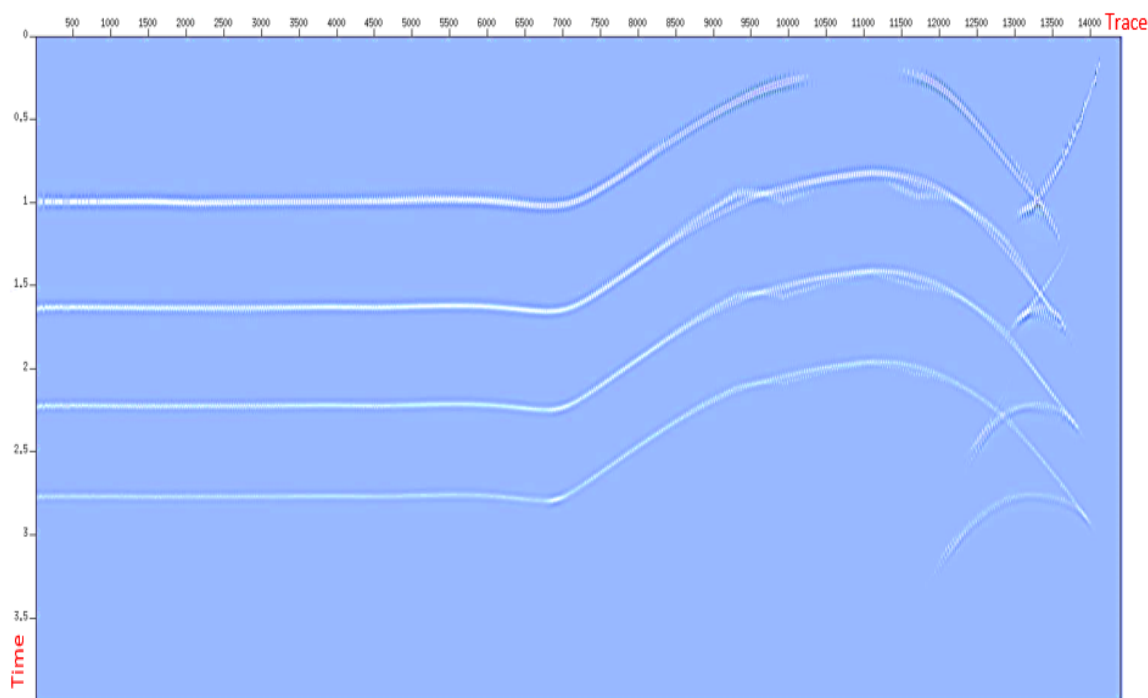


Fig. 7: Seismic section after NMO correction process and velocity analysis

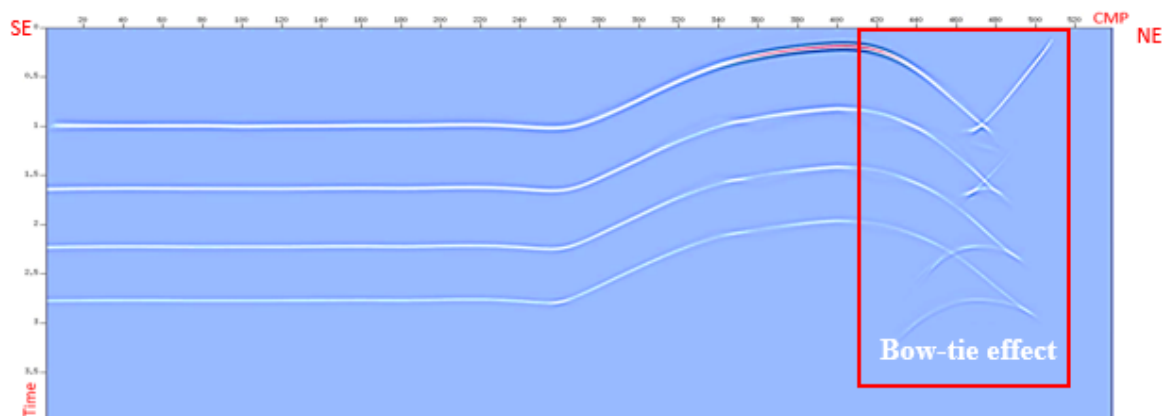


Fig.8: BS-92 stacked seismic section with Bow-tie effect for the simulated model

In this study, Stolt migrations were applied for post and pre-stack migration in the time domain. In Post-Stack time migration (PSTM); Stolt migration technique is applied with the following tested parameters: the chosen migrated velocity is 3500 m/sec (after testing from 1500 to 4500 m/sec with increment 500 m/sec), dip angle of migration operative is chosen to be equal to 30 degrees (which also tested from 10 to 60 degree), velocity smoothing and interpolation was chosen to be 100% (for tested values from 90% to 110% with increment 2%) and distance

between adjunct CDPs is chosen to be equals to 50 m (also tested from 30 m to 60 m). All these selected parameters (3500 m/sec, 30 degrees, 100% and 50 m) are the best result for the migration process (Fig. 9).

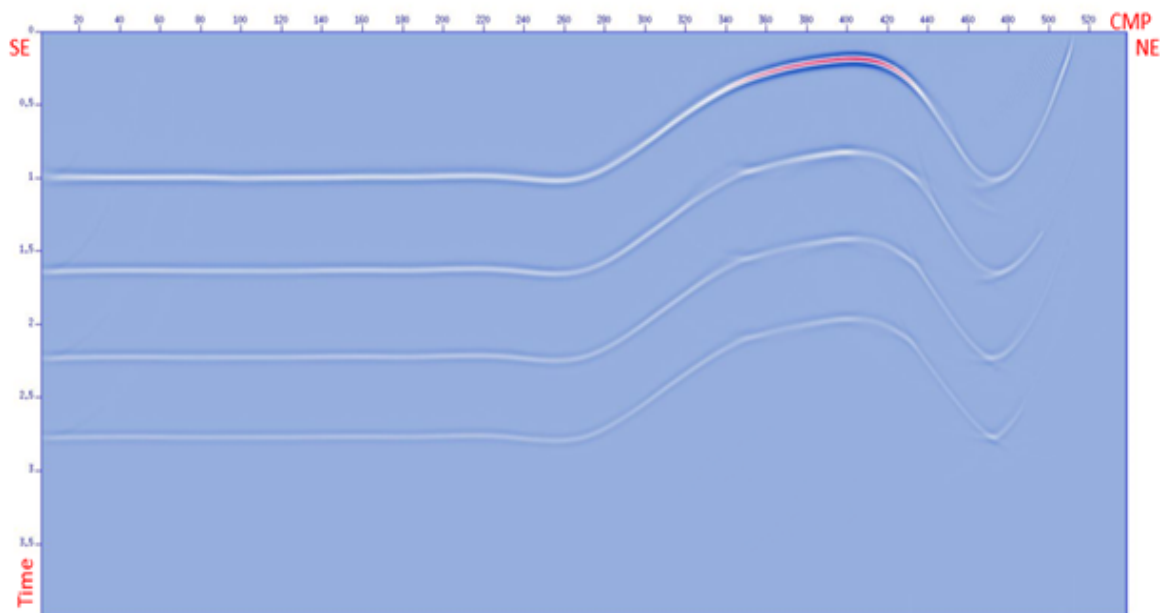


Fig. 9: BS-92 Post-Stack Time Migration section for the simulated model

The reflected synclines structure in the seismic image lengthwise with the time 0.5–2.7 sec image in the CMP range 320–440 becomes extra broadening after migration. So that, the Stolt migration corrects the structural geology and reorganize the seismic data to the corrected location. The imaging process returns with a side effect or dip noise in the edges area due to the migration operator, as well as the bow-tie effects that appear on the stacked section (red rectangular in Figure (8) are consume and twisted into synclines on the migrated stacked section (Fig. 9). Bow-ties (Fig. 10) can define as a concave-upward event in seismic data formed by a buried focus and corrected by the migration of seismic data. The focusing of the seismic wave result in three reflection points on the event for each surface location. The name was coined for the appearance of the event in immigrated seismic data. Synclines are commonly produced bow-ties. Synclines will be detected as “bow-ties.” As a result of their width on the seismic section is narrower than actuality and their structural depth is lessened. On the other hand, the anticlines will appear wider than they are. Finally, a point scattered will be detected as a hyperbola.

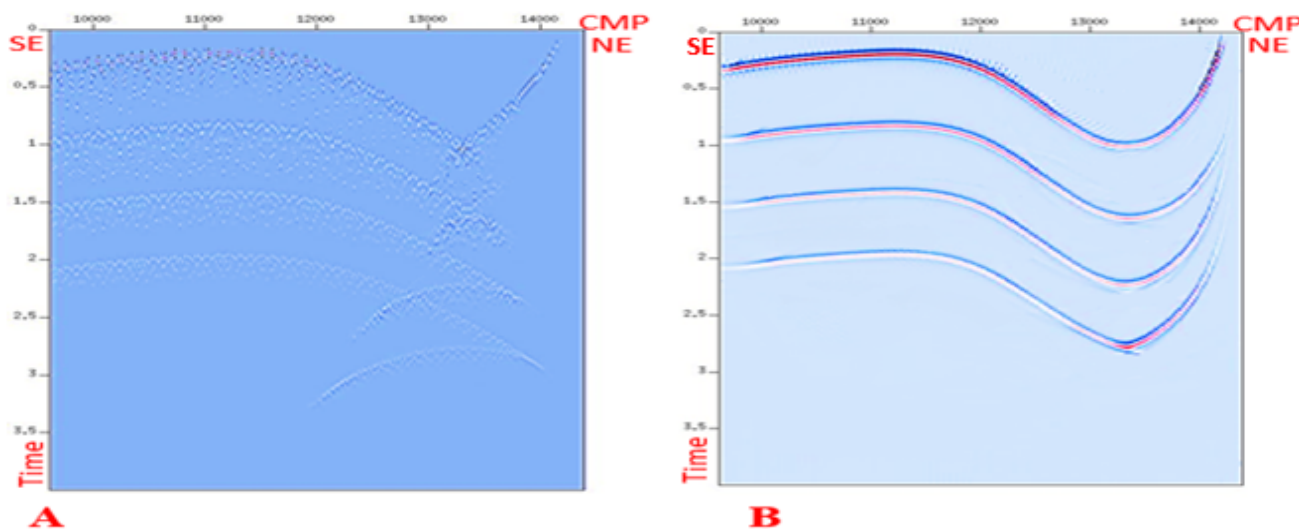


Fig. 10: Bow-tie effect (A) Stacked section and (B) Migrated stacked section

In the Pre-Stack time migration (Pre-STM), the processing has been prepared on the offset classes before stacking process, which is a type of data sorting, depends on the offset unit of the section. BS-92 simulated seismic line subdivided into 100 m offset as a single data processing with migration operations. In this condition, the velocity analysis also required to be re-picked and smoothing to get better velocity section before migration processing (Figs. 11 and 12). The parameters that were used in Post-Migration are also applied in the Pre-Migration processes added to them the offset number, the distance between adjacent CDP (m), the minimum and maximum number of CDPs for which to applied Dip Move-out (DMO). All these selected parameter (3500 m/sec, 30 degrees, 100%, 50 m, CDPmin=1, CDPmax=542) are the best result for migration operation. The results of the Pre-Migration process should be viewed in stack section which gives a clear displayed section so that can be matched with previous stacked sections. The results of this process are a migrated stacked section in Pre-migration formal (Fig. 13). Compared with the Post-stacked time migrated section, the Pre-migration section didn't show up the bow-tie effects due to the re-picked and smoothed velocity, migrated the reflections are correct their sites that are obstructed in seismic sections.

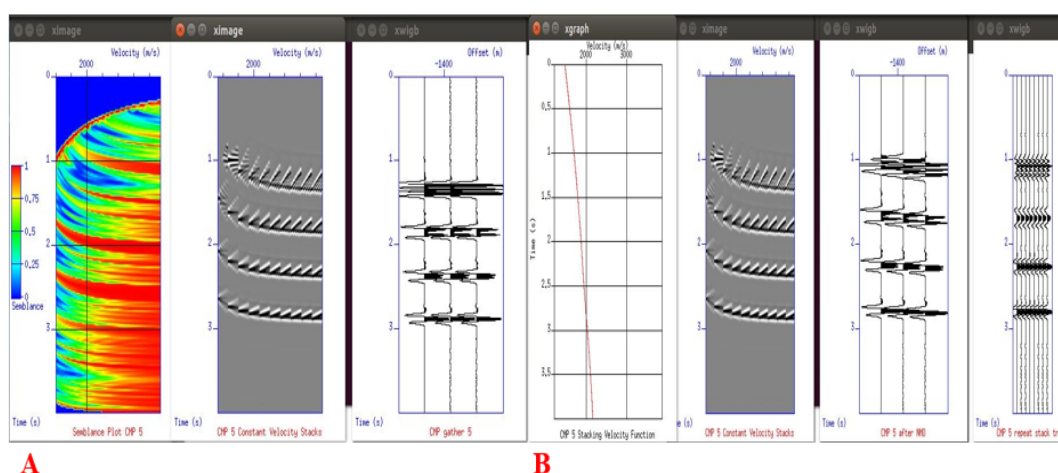


Fig. 11: Pre-stack time migration velocity analysis and smoothing
(A) Before and (B) After

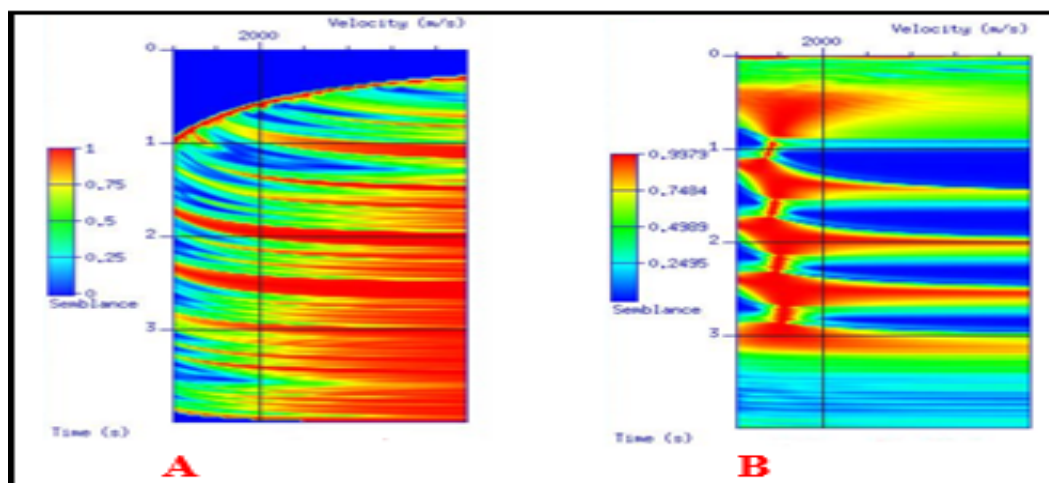


Fig. 12: (A) Offset classes without stack before re-picked. (B) Offset classes after re-picked velocity and smoothing

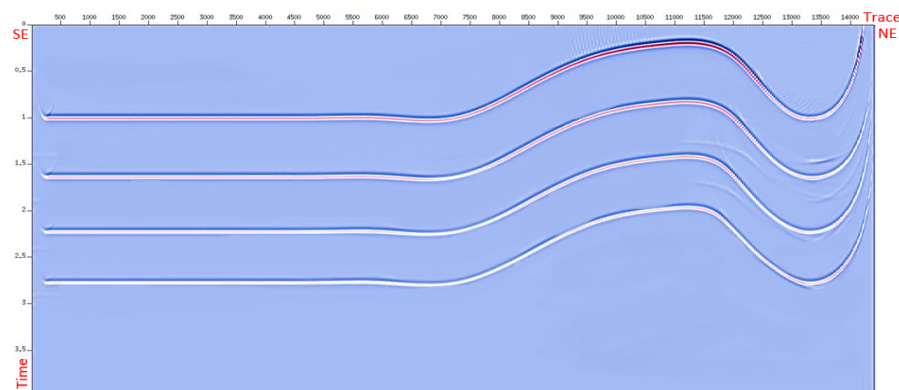


Fig. 13: BS-92 Pre-Stack time migration seismic section for the simulated model

DISCUSSION AND CONCLUSION

The open-source (Seismic Unix package) gives an ideal processing tool to re-pick and smooth the picked reflectors according to its velocity and time varieties. Stolt method provides a way of clarity that corrects the position of the up-dip of dipping events. The real BS-92 survey line has little horizontal velocity variant leads to variant the comparison between PSTM and Pre-STM on the stacked seismic section. The Pre-STM in the simulated model shows much reliable subsurface image with small changes in the edges of the seismic line. Also, velocity analysis (Figure (14) shows a clear evident that Pre-STM is better than PSTM. Because of the subsurface structures and structural complexity, the dipping events in the stacked migrated section are 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 given as noise and this is a mortal mistake. For a simple horizontal structure and low lateral velocities variants; Post-stack and Pre-stack give very similar image for the subsurface structures, while for complex features with high dips and good horizontal velocities variants the pre-stack is better than post-stack. The PSTM is faster in processing than Pre-STM, but the results may be slightly a little resolution than that 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 too short. This simulation study helps later in selected the correct parameters for migrating the real BS-92 survey line in Ajeel field.

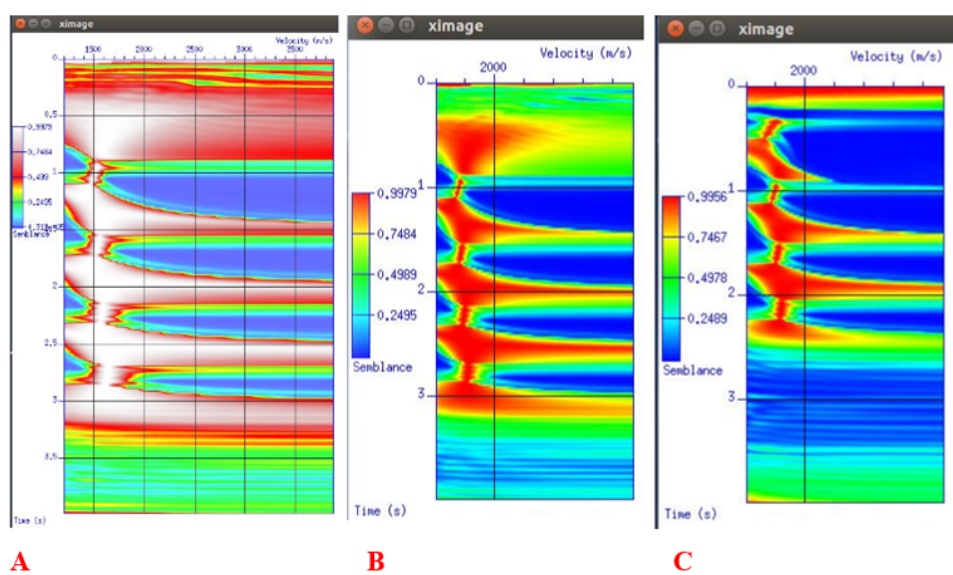


Fig. 14: (A) Stacked section, (B) Pre-stack migrated section, (C) Post-migrated section

REFERENCES

- Al-Ameri, K.T., Al-Jubouri, M.N., Isa, J.M., and Al-Azzawi, E.R., 2013. Hydrocarbons generation potential of the Jurassic–Lower Cretaceous Formation, Ajeel field, Iraq. *Arabian Journal of Geosciences*, Springer. DOI 10.1007/s12517-012-0636-0
- Aqrabi, A.M., Goff J.C., Horbury, D.A., and Sadooni N.F., 2010. *Petroleum Geology of Iraq*, published by scientific press Ltd, Beaconsfield, Bucks, UK and printed in Great Britain by Cambrian Printers, 403 pp.
- Bleistein, N., Stockwell, J.W., and Cohen, J.K., 2013. *Mathematics of Multidimensional Seismic Imaging, Migration and Inversion*. Springer, New York, NY.
- Claerbout, F.J., 1971. Toward a unified theory of reflector mapping, *Journal of Geophysics*, 36 (3):467-618.
- Fehler, M., and Huang, L., 2002. Modern imaging using seismic reflection data, *Annual Review of Earth and Planetary Sciences*, (30): 259-284.
- Forel, D., Benz, T., and Pennington, W.D., 2005. *Seismic Data Processing with Seismic Unix: A 2D Seismic Data Processing Primer*. Society of Exploration Geophysicists.
- Gardner, G.H.F., 1985. *Migration of Seismic Data*: Tulsa, OK, Society of Exploration Geophysicists, Monograph Series, 462 pp.
- Gray, J.S., Denlinger, E.J., and Whitmore, D. 2001. Seismic migration problems and solutions. *Geophysics*, 66: 1622–1640.
- Jassim, S.Z., and Goff, J.C., 2006. *Geology of Iraq*, Published by Dolin, Prague and Moravian Museum, Burro.
- Lindseth, O.R., and Geoph, P., 1982. *A Review of Digital Processing of Geophysical Data*. Society of Exploration Geophysicists.
- Lorenzo, J.M., 2018. December. Graphical user interface useful for building seismic flows from Seismic Unix. In AGU Fall Meeting Abstracts.
- Prado, A.H.D., Almeida, R.P.D., Tamura, L.N., Galeazzi, C.P., and Ianniruberto, M., 2019. Interpretation software applied to the evaluation of shallow seismic data processing routines in fluvial deposits. *Brazilian Journal of Geology*, 49(2).
- Reynolds, M.J., 1997. *An Introduction to Applied and Environmental Geophysics*.^{1st}ed. Published by Sons & Wiley, 367-377 pp.
- Stolt, R.H., 1978. Migration by Fourier transform. *Journal of Geophysics*, 43(1): 23-48.
- Stolt, R.H. and Wegleint A.B., 1985. Migration and inversion of seismic data. *Journal of Geophysics*, 50(12): 2458-2472.
- Yilmaz, O., 2001. *Seismic Data Analysis: Processing, Inversion and Interpretation of Seismic Data*, Society of ExplorationGeophysicist