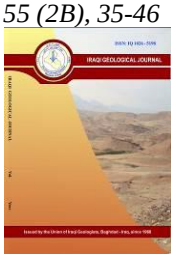
Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org



Subsurface Imaging of the Fatha Formation Utilizing 3D Seismic Data in Chia Surkh Area, Kurdistan Region, Iraq

Faris H. Yousif[1,2,*], Bakhtiar Q. Aziz[1] and Ezaddin N. Baban[1]

[1] Department of Geology, College of Science, University of Sulaimani, Sulaimani, Kurdistan Region, Iraq
[2] Department of Environmental Science, Faculty of Science, University of Zakho, Zakho, Kurdistan Region, Iraq
[*] Correspondence: faris.yousif@uoz.edu.krd

Received:
5 February 2022

Accepted:
14 May 2022

Published:
31 August 2022

Abstract

The current study aims to detect subsurface geologic features using 3D dense sampling seismic data in the Fatha Formation, in the Chia Surkh area, Kurdistan Region,Iraq. A3D cube seismic data covering 75 Km^2 were used to image the Fatha Formation subsurface geologic structures. The seismic data and appropriate information were gathered from Pet Oil Company with the permission of the Ministry of Natural Resources of the Kurdistan Region, Iraq. A cube of seismic data was used to image the three units of the Fatha Formation. In this study, forty seismic sections with the direction of NE-SW and 30 crossline sections of NW-SE direction were used. The map shows the existence of several features such as a three-way dip closure elongated NW-SE and extended through the whole study area. The reflector three of the Fatha isochron map shows TWT ranging from 890 ms to 1720 ms. The depth map of Fatha unit 1 Formation, shows depth with seismic reference datum ranging from 838 m to 2334 m. The study concluded the existence of several structural features; a major anticline trending with Zagros belt trend, and three longitudinal systematic reverse faults on the southwest side of the anticline, leading to the possibility for which the area is considered as a prospective oil reservoir, might work as a good trap, an anticline, evaporites work as a seal and limestone rocks as a reservoir.

Keywords: 3D seismic data; Subsurface imaging; Structural interpretation; Chia Surkh; Kurdistan Region

1. Introduction

Seismic reflection data interpretation is a technique that is widely being used to deduce subsurface geology information exploiting the processed seismic data. After decades of physical and mathematical innovations, geoscientists now have the ability to apply 3D seismic surveys across sedimentary basins. These three-dimensional data provide a better understanding of the subsurface complexity (Paumard et al., 2019) . The role of seismic reflection gives more direct and detailed picture of the subsurface geological structures. The seismic sections, time, and velocity contour maps are used to determine a structural trap and seismic stratigraphy as well as seismic facies (Chima et al., 2019), (Al-Rubaye et al., 2019). A 3D Seismic data is considered a revolution in the hydrocarbon industry to understand the subsurface. Seismic interpretation is directed to understanding the geology subsurface image, delineates structural traps by mapping the top of a reservoir (Manzi et al., 2020). Seismic interpretation provides an evaluation of the hydrocarbon potential of a prospect as low and identifies the best location for drilling

DOI: 10.46717/igj.55.2B.4Ms-2022-08-20

wells (Gadallah and Fisher, 2008). Moreover, detecting subsurface geologic structures (Tao and Alves, 2019), (Miraj and Idrees, 2021).The dense sampling of a 3D survey is capable to map reservoirs and distribution of hydrocarbons. The importance of this technique is utilized in this study to detect structural geologic features in the Fatha (Lower Fars) Formation, which has a vital role as a caprock and as a reservoir in many hydrocarbon fields in Iraq (e.g., Kirkuk field, (Dunnington, 1958). A 2D Seismic study for the area and surroundings to detect subsurface structures was previously conducted by (Baban et al., 2014). The study area (Fig. 1) lies in Kurdistan Region, the northeastern part of Iraq (20) Km east of Kalar town, approximately 70 km south southeast of Sulaimani governorate covering 75 Km^2 and bounded by the coordinates (Table 1). This study aims to exploit and interpret intense sampling 3D seismic data to image the subsurface structures, horizons, anticlines , faults and possibility of hydrocarbon traps existence.

Table 1. Coordinates of the study area

No.	Latitudes	Longitude
1	34˚ 42′ 7.0645″N	45˚ 36′ 16.9517″E
2	34˚ 39′ 10.4738″N	45˚ 32′ 53.4541″E
3	34˚ 42′ 51.8791″N	45˚ 28′ 4.6001″E
4	34˚ 45′ 47.5386″N	45˚ 31′ 28.0746″E

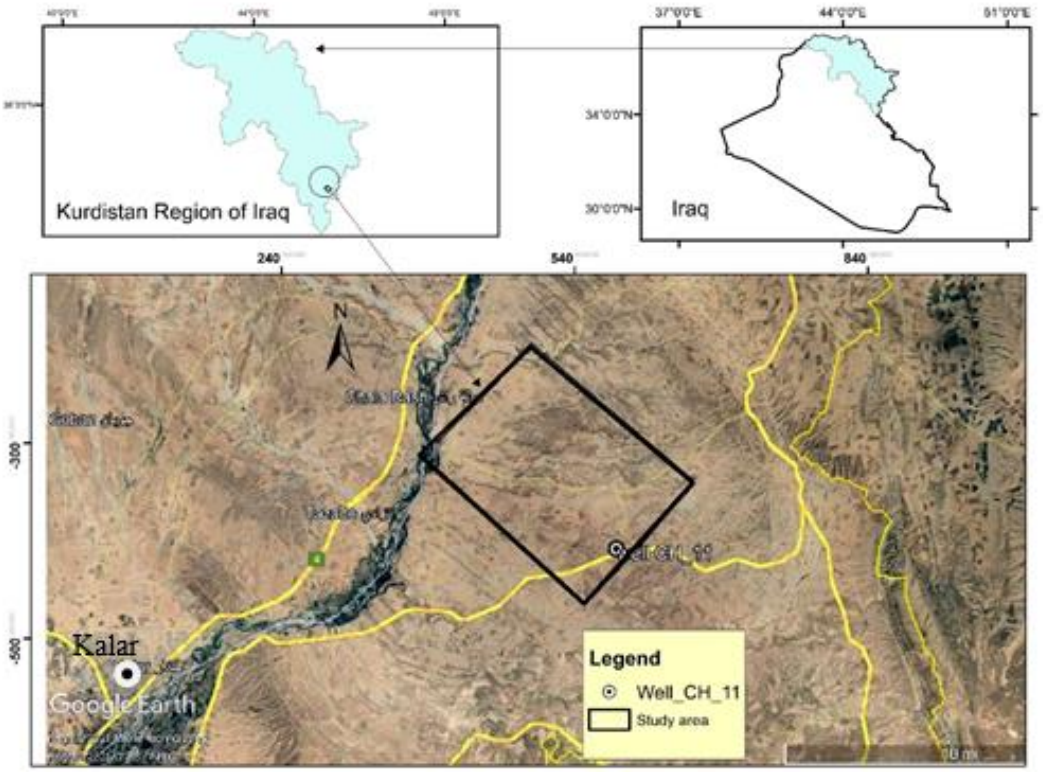


Fig. 1. Location of the study area

2. Geology and Tectonic Setting

The Middle Miocene Fatha Formation is widely covering Iraqi teroteries (Al-Juboury and McCann, 2008); (Jassim and Goff, 2006); (Sissakian and Fouad, 2015). It consists of evaporites, deposited in lagoons, many cycles of alternating limestones, claystone, anhydrite, gypsum, and halite. The

deposition environment for the M. Miocene Fatha Formation in northern Iraq, was a wide, broad, and shallow elongated basin located next to Zagros and Taurus mountain series (Sissakian et al., 2016). The Fatha Formation for its importance has been studied and mentioned in many papers and few books (Jassim and Goff, 2006); (Shawkat and Tucker, 1978). Chia Surkh area is generally of low relief with reasonable accessibility. The area is mainly within the low folded zone neighboring high folded zone (Fouad, 2010). In the Chia Surkh area, the exposed lithostratigraphic units are mainly Miocene aged (Fig. 2) (Adams et al., 2013). The geological column of the well CS-11 in the study area shows the existence of the following formations from the; youngest to the oldest Injana (Upper Fars) Formation (Late Miocene), which outcrops widely along the Chia Surkh anticline. The formation is mainly composed of claystone and sandstone alternations. The thickness of sandstone beddings is 2 to 6 m, occasionally 10-20 meter in the outcropbrown, the color changes from brown to reddish brown to greyish brown, the beds are fine to medium-grained with cross-bedding, ripple marks and laminations. The claystones are reddish-brown colored. Fatha lithofacies are divided into 4 units from well CS-11, and described by (Adams et al., 2013). Unit 1 is exposed widespread along the Iranian boundary at the eastern part of the Chia Surkh anticline. Starting from bottom to the upper section of the formation, marl-limestone alternation, anhydrite with frequent marl, claystone, limestone, red claystone with frequent marl, limestone and less frequent anhydrite and upper red beds with sandstone, siltstone and rare anhydrite intercalation. Fatha Formation – unit 2 comprises anhydrite with interbedded siltstone and mudstone. Unit 3 of this formation is composed of rock salt and anhydrite with some siltstones, mudstones and with less frequent limestone intercalations. Eventually unit 4 is composed of anhydrite, mudstone and thin limestone beds usually overlie the so-called "Basal Fars Conglomerate. The study area is placed in the north east of the Arabian Plate and adjacent to the Zagros Fold- Thrust Belt which was a result of collision between the Arabian and Eurasian plates (Ameen, 1992); (Fouad, 2010). Also, the study area is a part of the low folded thrust zone (Ameen Lawa and Ghafur, 2015). The NW-SE fault system is a characteristic for this zone, which was created during the Lower Miocene taking trend same as Tauros in the north and Zagros in north east folding series.

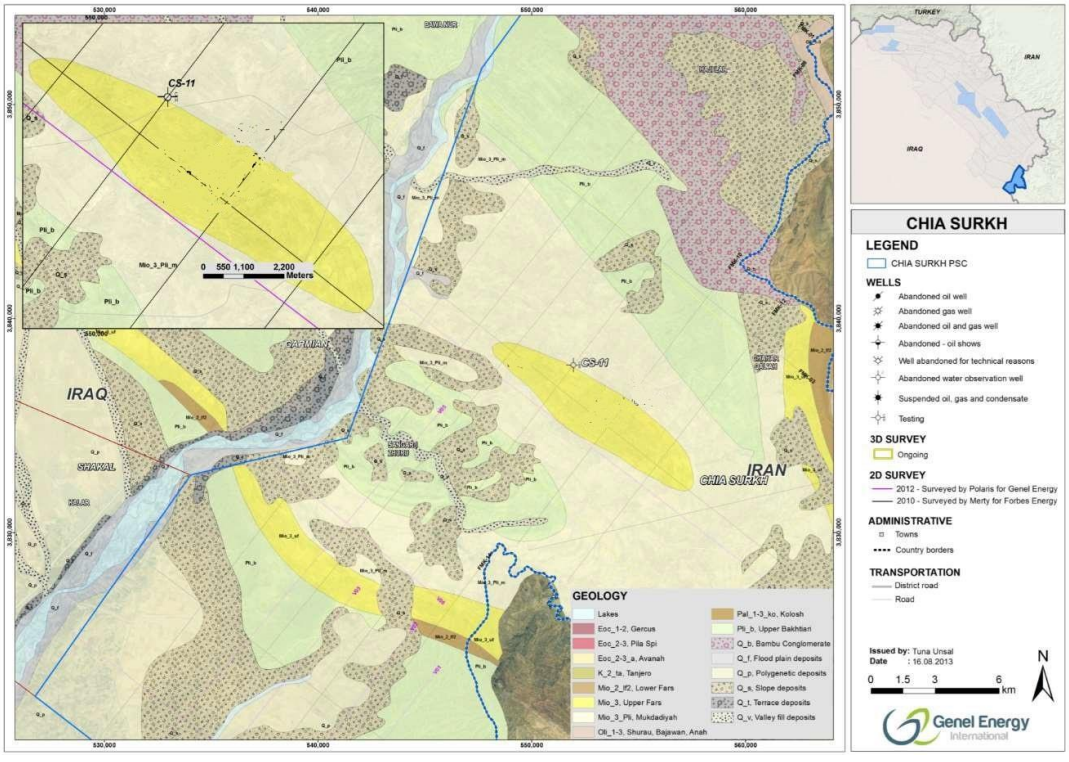


Fig. 2. Geology map of the study area(after Genel Energy)

3. Materials and Methods

A cube of seismic data covering 75 Km^2 was used to image the Fatha Formation subsurface geology. Pet Oil Company provided the seismic data and appropriate information with the permission of the Ministry of Natural formationResources (MNR) of the Kurdistan region-Iraq (KRI). A cube of seismic data is used to image the three units of the Fatha Formation. In this study, 40 inline sections with direction (NE-SW) and 30 crossline sections (NW-SE) direction sections are used, the length of the seismic line is equal to 7.5 by10 km, and the distance between each seismic line and the next is 250 meters, also providing data logs of one well CS-11 (Fig. 3). Seismic data and senthetic seismogram of the well CS-11, helped piking all units of Fatha Formation unit one, two, and three, correlated, and linked, using Petrel Schlumberger 2017 software. The tops of the three reflectors are identified (Fig. 4) and (Fig. 5). Isochrone maps (Figs. 6, 7, 8) and depth maps (Figs. 9,10 and 11) are constructed. Three Faults 1, 2 and 3 are identified and depicted on all three depth maps.

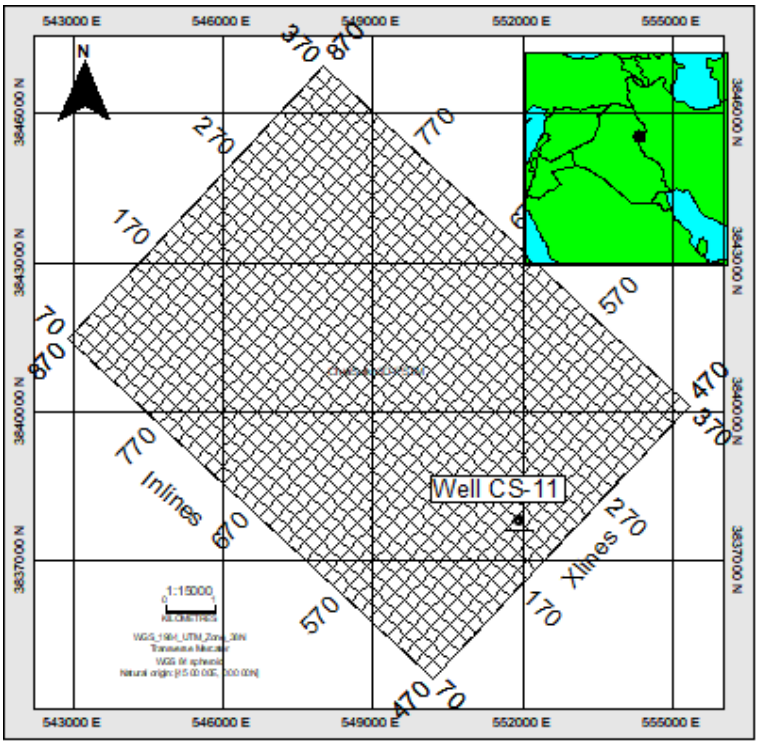


Fig. 3. Seismic lines base map

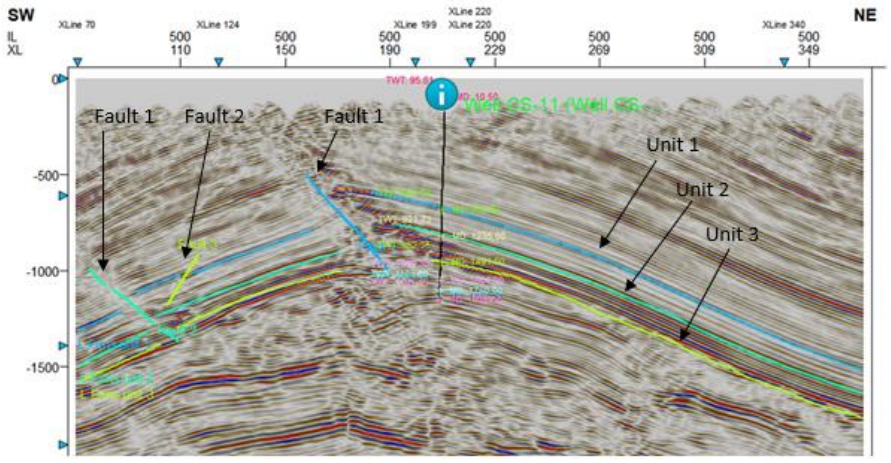


Fig. 4. Interpretation of seismic inline 500

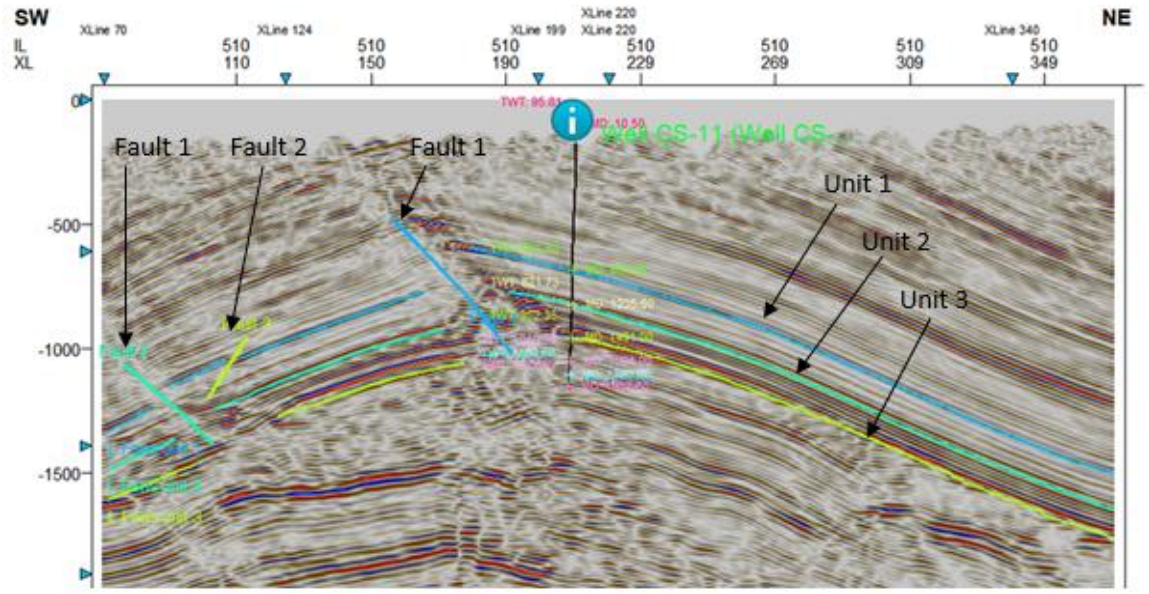


Fig. 5. Interpretation of the seismic inline 510

4. Results and Discussion

4.1. Isochron (TWT) Maps

The isochron maps of the three reflectors unit 1, unit 2 and unit 3 of the Fatha Formation have been deduced and plotted in Figs. 6, 7 and 8. The maps reflects the presence of several features in time domain such as four-way dip closures and narrowing contours. The isochron maps from younger to older age of Fatha reflectors as follows; Reflector 1, Fig. 6 shows TWT ranging from 550 ms to 1500 ms. The map shows the existence of several features such as a three-way dip closure elongated NW-SE and extended through the whole study area. The isolines on the NE side are broad means dipping less while they are tighter on the SW side reflects more dipping. The second feature noticed is isolines are narrowing refer to more inclination in NW-SE direction on the left side of the three-way dip closure extending from SE to the NW of the study area. The Reflector 2 of the Fatha Formation Fig. 7 shows TWT ranging from 750 ms to 1640 ms. The map shows the same features in Unit 1, such as a three-way dip closure elongated NW-SE and extended through the whole study area. the isolines on the NE side are broad while they are tighter on the SW side. The second feature noticed is isolines narrowing in NW-SE direction on the left side of the three-way dip closure extending from SE to the NW of the study area besides indications of another small four-way dip closure in the SW side of the area. The Reflector 3 of the Fatha Formation isochron map Fig. 8 shows TWT ranging from 890 ms to 1720 ms. The map shows development of a closure under depth of 1200 ms located in the NW side separated from main elongated closure left as a giant dome under depth of 1000 ms.

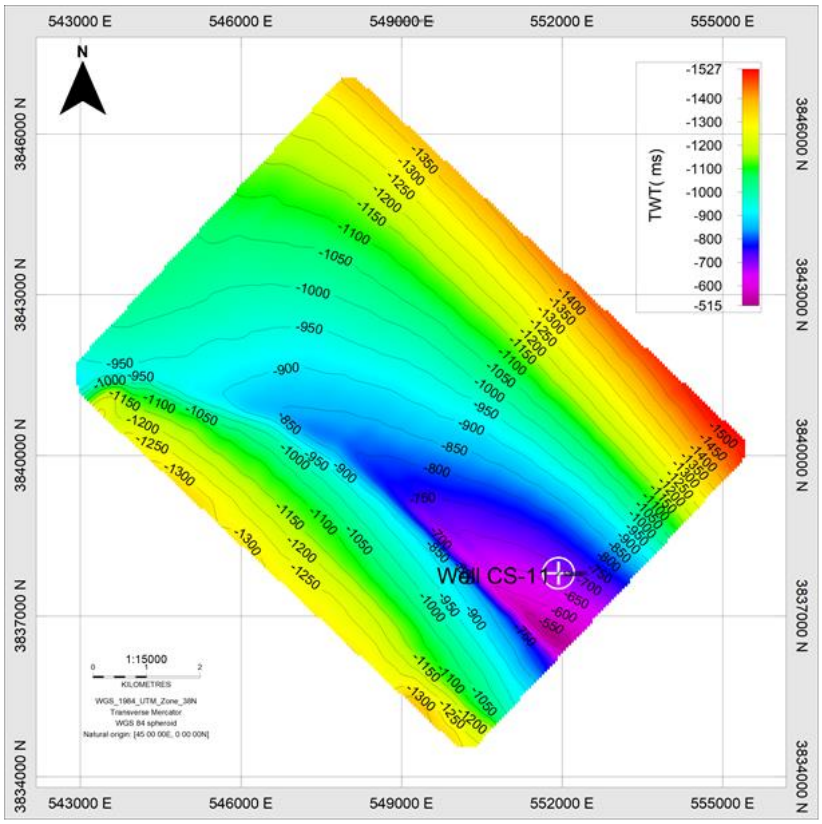


Fig. 6. Fatha reflector 1 (TWT Map)

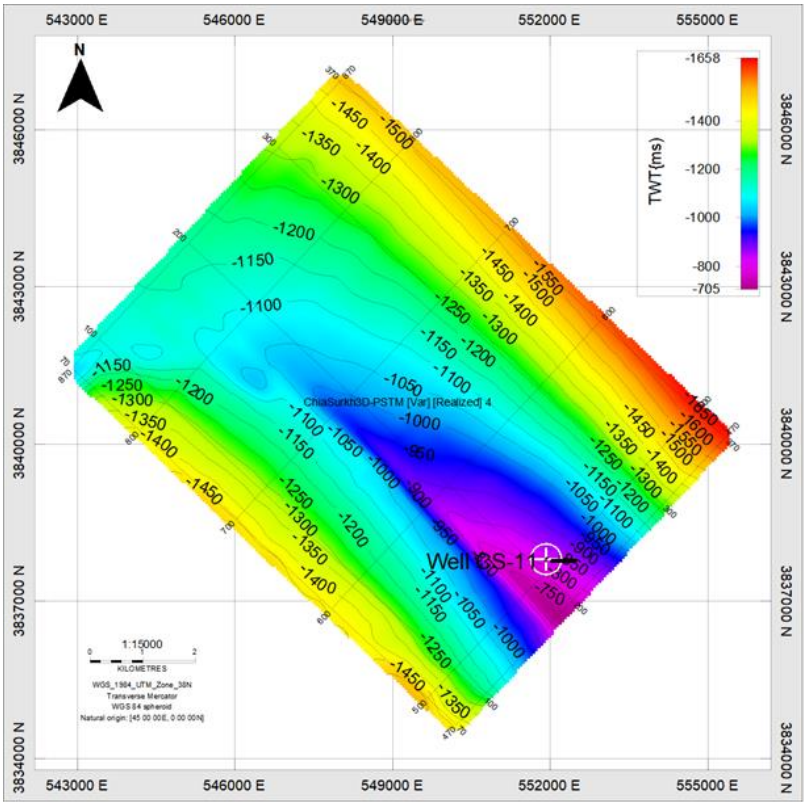


Fig. 7. Fatha reflector 2 (TWT Map)

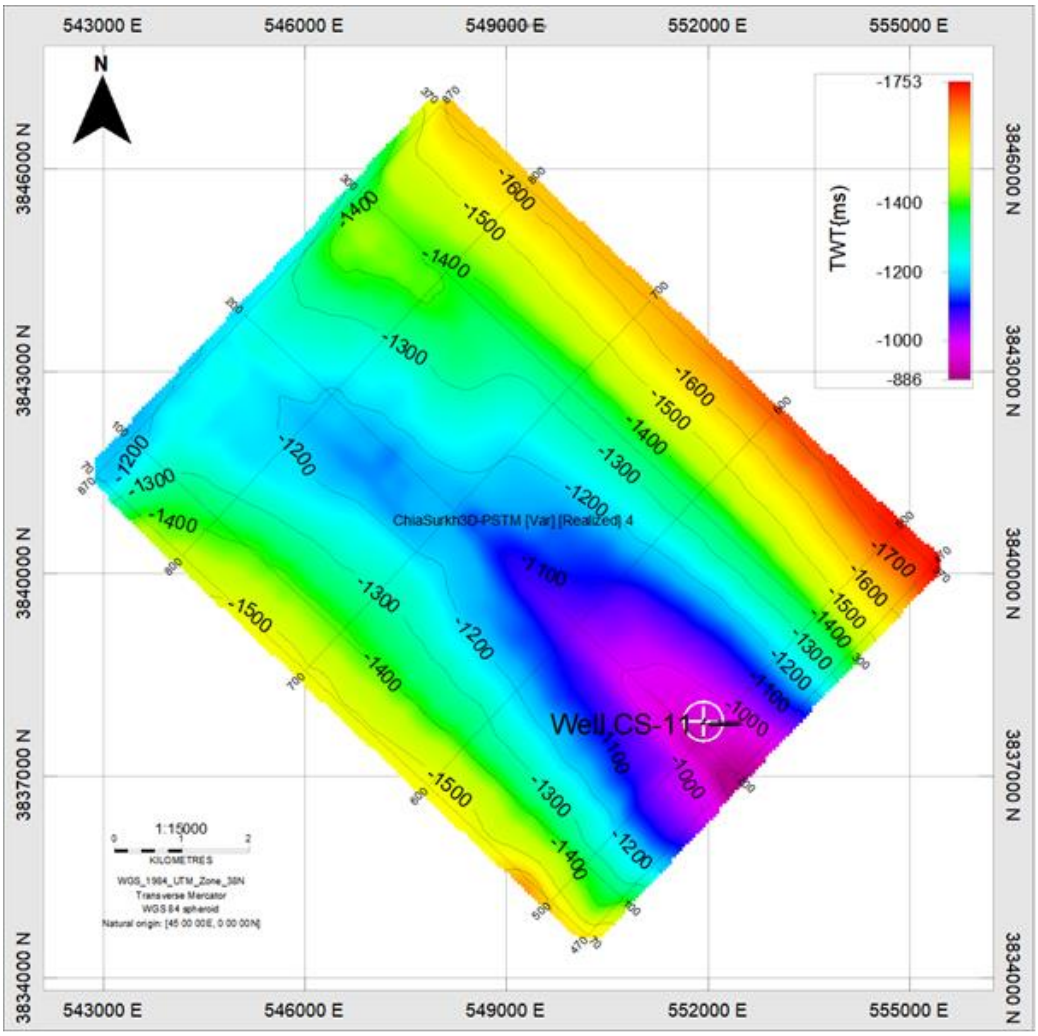


Fig. 8. The Fatha Formation reflector 3 (TWT Map)

4.2. Depth Maps

Three units of the Fatha Formation maps unit one ,unit two and unit three are constructed in depth domain (Figs. 9, 10 and 11), utilizing a fixed velocity value for each horizon (Faust, 1951; Marsden, 1989), due to homogeny in the area (GL internal contact). The depth map of unit 1 of the Fatha Formation, Fig. 9 shows depth with Seismic reference datum (SRD) ranging from 838 m to 2334 m. An anticline trending NW-SE extending 10 Km and continues in SE side out of the study area, and 7 Km in width plunging in the NW side of the area. The NE limb is dipping about 30˚ which is broader than the SW limb, which is dipping about 45˚. Three systematic reverse longitudinal faults picked Fault 1, 2, 3 with NW-SE strike direction. Faults 1 and 2 have NE dip direction while Fault 3 has SW dip direction. Fault 1 is the main one, passing through the entire study area from NW to SE for about 10 km, penetrating the Fatha Fm. unit 1 from top to the bottom, dipping about 45°, and having a throw of 100-150 m. Fault 2 extends 2.1 km through Fatha Fm. unit 1, inclined about 45°, and has a throw of 40 m. Fault 3 extends 2 kilometers, penetrating the top part of the Fatha Formation. unit 1 but not reaching the underneath unit, dipping about 40 °, and has a throw of 15 meters.

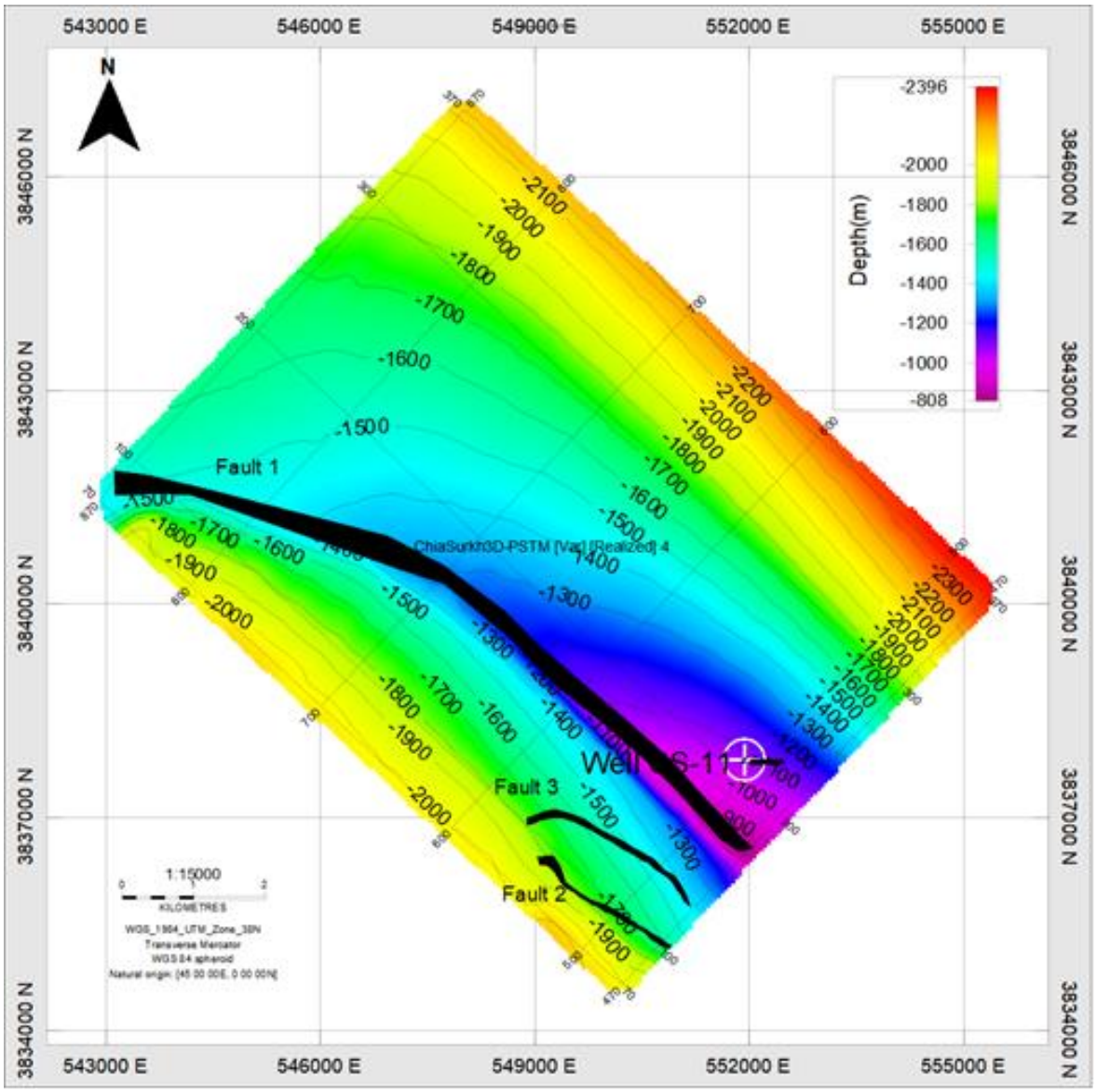


Fig. 9. Depth map (Fatha unit 1)

The depth map of the Fatha Formation unit 2 (Fig. 10) shows depths ranging from 1150 m to 2600 m . An anticline trending NW-SE extending 10 kilometers, with a width of 7 kilometers sinking on the NW side. The NE limb dips around 45 °, whereas the SW limb dips about 30 °. Fault 1 and 2 are longitudinal faults with NW-SE strike direction and dipping to the northeast. Fault 1 extends from NW to SE for about 10 km, penetrating unit 2, inclined about 45°, and has a throw of 100-150 m. Fault 2 extends 2.1 km through unit 1 to the bottom, inclined about 45°, and has throw of 40 m.

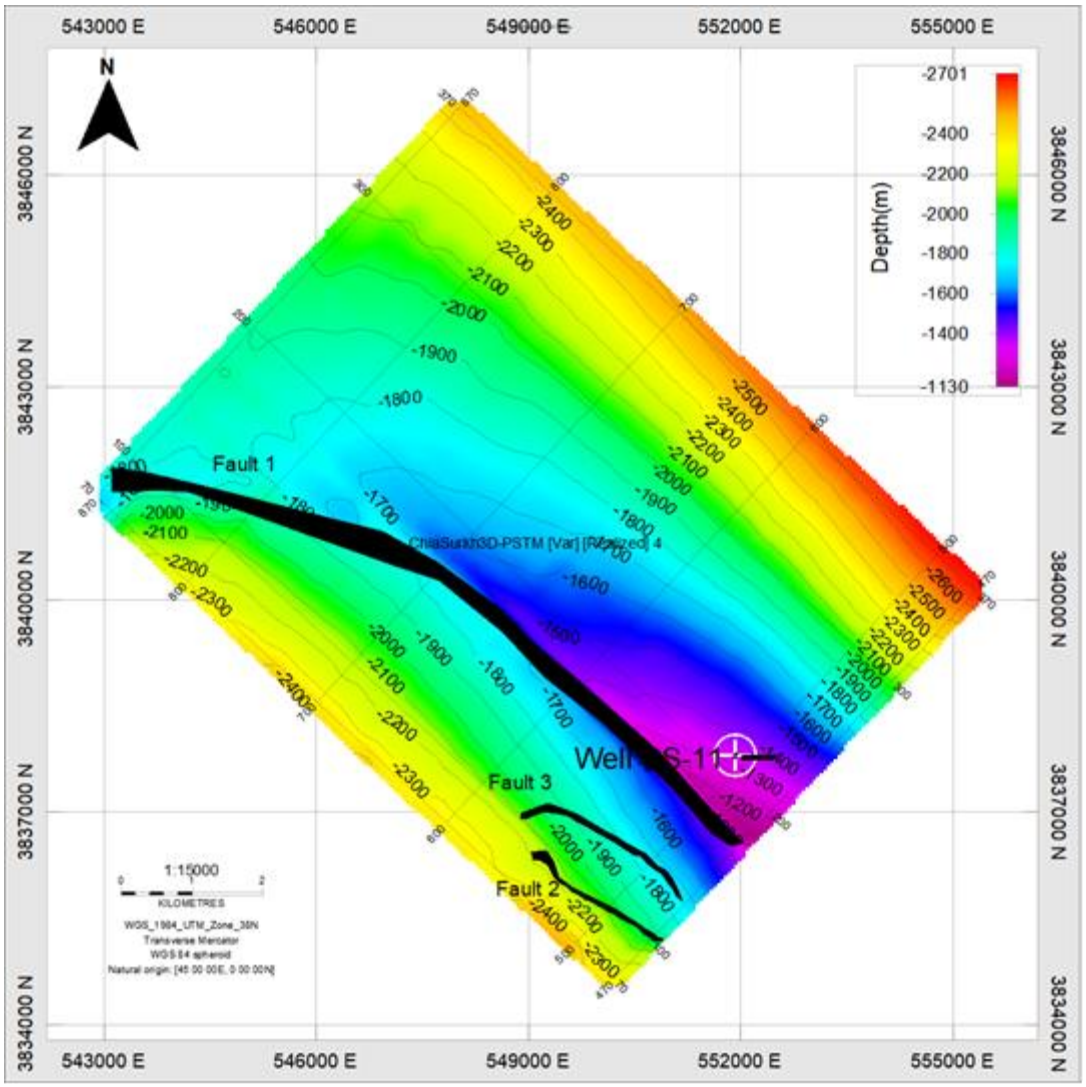


Fig. 10. Depth map (Fatha unit 2)

Depth map of the Fatha unit 3 (Fig. 11), reveals depths ranging from 1500 m to 2780 m. An anticline trending NW-SE extending 10 km, and 7 km wide plunging in the NW side of the area. The NE limb inclination is approximately 30°, which is greater than the SW limb dip of approximately 45°. Fault 1, 2 are reverse longitudinal faults with a strike direction of NW-SE, parallel and dipping NE directions Fault No. 2 extends 2.1 Km intersecting Fatha Formation unit 1, dipping about 45°, and has a throw of 40 m. The structural features shown in all maps are the same features continuing in-depth penetrating the three units of the Fatha Formation (Fig. 12 a & b). These geologic structures are adequate and coincide with the structural elements in the High and Low Folded zones, which are parallel and show well-developed large lineament seen in the field and aerial photography and satellite images representing anticlines and faults. The development of these anticlines is related to the collision of Iranian and Arabian Plates and migration of the tectonic deformation towards the southwest inside Iraq, thrusting developed along Paleocene-Miocene (Le Garzic et al., 2019). The lengths of most of these anticlines are around10-30 km (Jassim and Goff, 2006). The anticline structure outlined in this study is a NW-SE trending structural feature located along the major Kirkuk structural trend. The anticline in the study area is affected by two minor and a major NW-SE trending, northeast dipping thrust Faults. Fault 1, the major one is located on the south west limb of the anticline, its place close to the crest caused the escape of volatile parts of the hydrocarbons, as leaks in the area refer to that, on the other hand, the

presence of the interbedded claystone might cause clay smear mechanism which is leading to smearing the fault surface and sealing it as a kind of mineralization saving the rest of the hydrocarbons in the prospective environment.

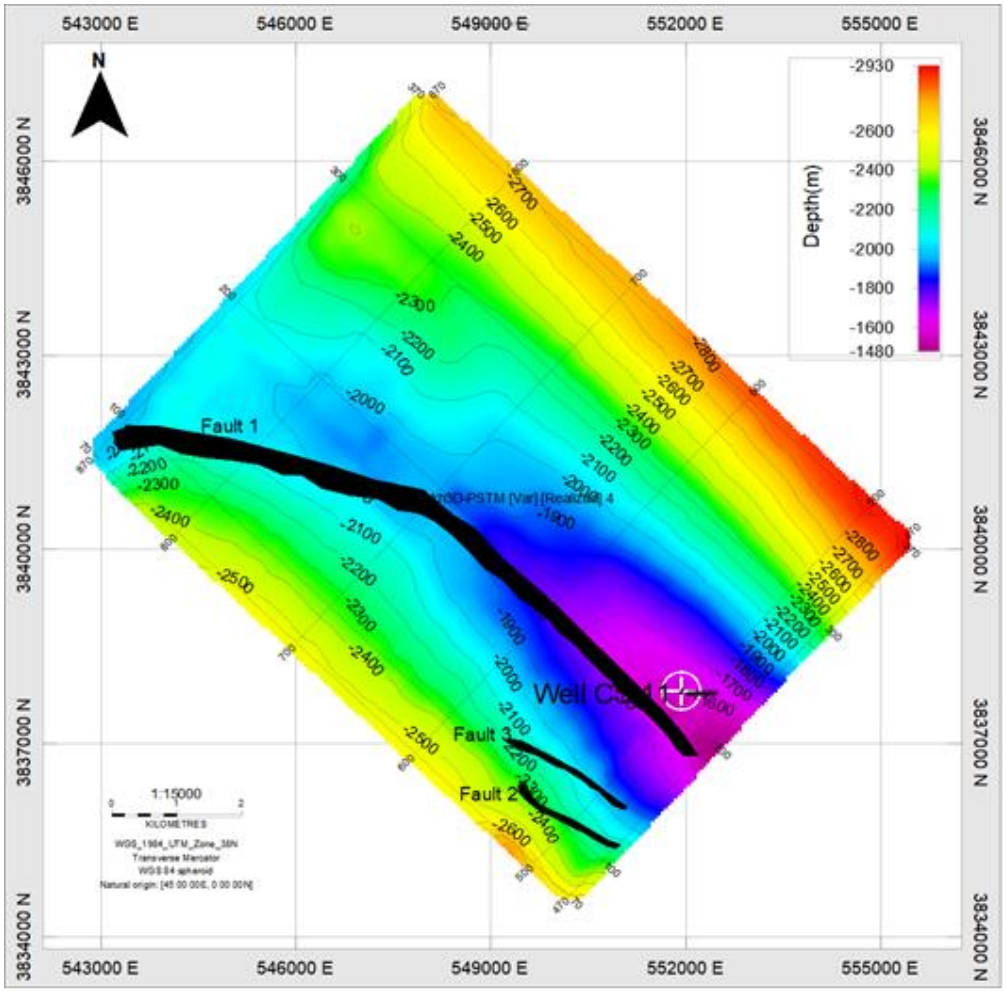


Fig. 11. Depth map (Fatha unit 3)

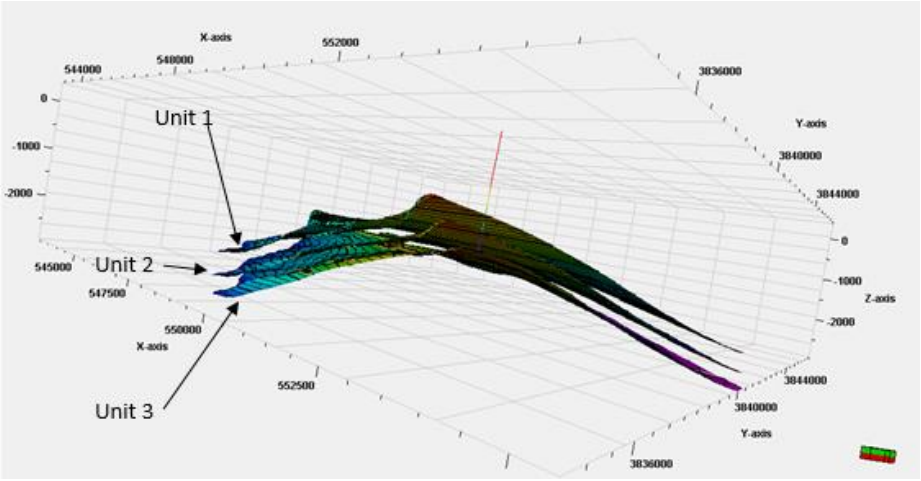


Fig. 12 (a). 3D depth maps of the three units of the Fatha Formation

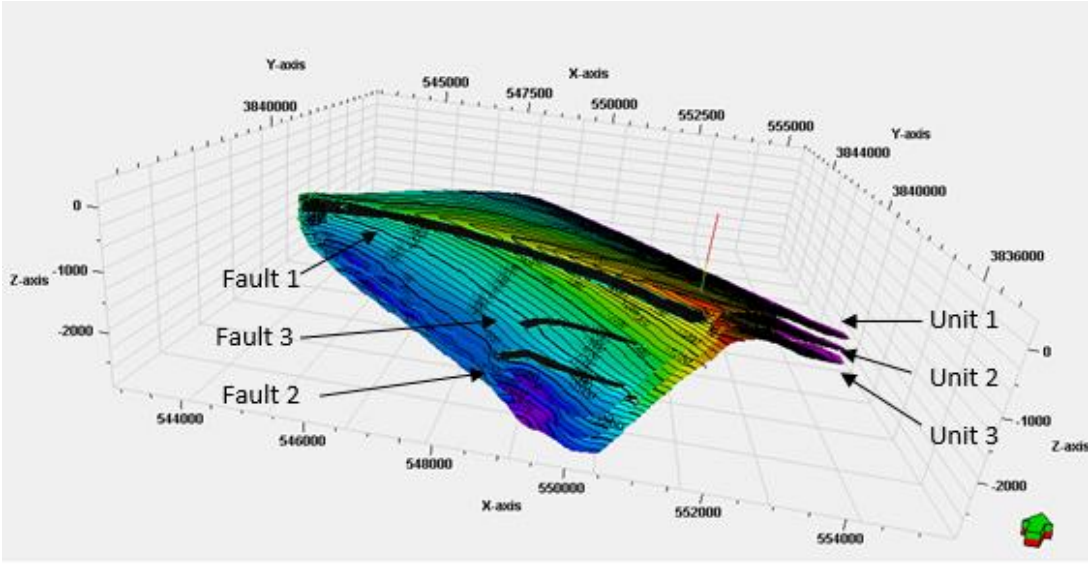


Fig. 12(b). 3D depth maps of the three units of the Fatha Formation

5. Conclusions

The study concluded the existence of several structural features; a major anticline trending NW-SE strike direction coinciding with the ZFTB trend and three longitudinal systematic reverse faults situated on the SW side of the Chia Surkh anticline. The structures developed during Alpine Orogeny movements during the Early Miocene age. The study area is nominated to be an oil prospective, as it works as a good trap, an anticline with evaporites work as a seal, and limestone as a reservoir. It is worth mentioning that the major fault intersects the anticline close to the crest and causes the escape of volatile components of the hydrocarbons as leaks in the area refer to that. Still, the interbedded claystone beds might cause clay smearing and mineralization of the fault surface, saving the rest of the hydrocarbons.

Acknowledgements

The authors are very grateful to the Ministry of Natural Resources, Kurdistan Region of Iraq, Pet Oil Company for providing the 3D seismic data. The authors are very grateful to the reviewers, Editor in Chief Prof. Dr. Salih M. Awadh, the Secretary of Journal Mr. Samir R. Hijab, and the Technical Editors for their great efforts and valuable comments.

References

Adams, S., Abalioglu, I., Yıldızel, A., Mather, B., Flood, A., Onguner, B., Araque, A., Sallier, B. & Martinuzzi, V., 2013. Final Geological Report Well CS-11. Unpublished

Al-Juboury, A. I. & McCann, T., 2008. The Middle Miocene Fatha (Lower Fars) Formation, Iraq. GeoArabia, 13, 141-174.

Al-Rubaye, H. H., Gayara, A. D. & Hussien, A. A. 2019. Facies analysis and stratigraphic development of the Zubair Formation in the Mesopotamian Zone, Southern Iraq. Iraqi Journal of Science, 290-307.

Ameen Lawa, F. A. & Ghafur, A. A. 2015. Sequence stratigraphy and biostratigraphy of the prolific late Eocene, Oligocene and early Miocene carbonates from Zagros fold-thrust belt in Kurdistan region. Arabian Journal of Geosciences, 8, 8143-8174.

Ameen, M. 1992. Effect of basement tectonics on hydrocarbon generation, migration, and accumulation in northern Iraq. American Association Petroleum Geolosits, 76, 356-370.

Baban, E. N., Aziz, B. Q. & Aziz, N. H. 2014. Study of subsurface structures using seismic reflection data for Kalar–Khanaqin area, Kurdistan Region, Iraq. Arabian Journal of Geosciences, 7, 2279-2291.

Chima, K. I., Do Couto, D., Leroux, E., Gardin, S., Hoggmascall, N., Rabineau, M., Granjeon, D. & Gorini, C. 2019. Seismic stratigraphy and depositional architecture of Neogene intraslope basins, offshore western Niger Delta. Marine and Petroleum Geology, 109, 449-468.

Dunnington, H. V. 1958. Generation, migration, accumulation, and dissipation of oil in northern Iraq: Middle East.

Fouad, S. F. 2010. Tectonic and structural evolution of the Mesopotamia Foredeep, Iraq. Iraqi Bulletin of Geology and Mining, 6, 41–53.

Gadallah, M. R. & Fisher, R. 2008. Exploration geophysics, Springer Science & Business Media.

Jassim, S. Z. & Goff, J. C. 2006. Geology of Iraq, DOLIN, sro, distributed by Geological Society of London.

Le Garzic, E., Vergés, J., Sapin, F., Saura, E., Meresse, F. & Ringenbach, J. 2019. Evolution of the NW Zagros Fold-and-Thrust Belt in Kurdistan Region of Iraq from balanced and restored crustal-scale sections and forward modeling. Journal of Structural Geology, 124, 51-69.

Manzi, M. S., Cooper, G. R., Malehmir, A. & Durrheim, R. J. 2020. Improved structural interpretation of legacy 3D seismic data from Karee platinum mine (South Africa) through the application of novel seismic attributes. Geophysical Prospecting, 68, 145-163.

Miraj, M. A. F. & Idrees, M. Z. 2021. Subsurface structural interpretation of Missa Keswal Area, Eastern Potwar, Pakistan. The Iraqi Geological Journal, 146-156.

Paumard, V., Bourget, J., Durot, B., Lacaze, S., Payenberg, T., George, A. D. & Lang, S. 2019. Full-volume 3D seismic interpretation methods: A new step towards high-resolution seismic stratigraphy. Interpretation, 7, B33-B47.

Shawkat, M. G. & Tucker, M. E. 1978. Stromatolites and sabkha cycles from the Lower Fars Formation (Miocene) of Iraq. Geologische Rundschau, 67, 1-14.

Sissakian, V., Karim, S., Al-Kubaisy, K., Al-Ansari, N. & Knutsson, S. 2016. The Miocene sequence in Iraq, a review and discussion on the stratigraphy, paleogeography and economic potential. Journal of Earth Sciences and Geotechnical Engineering, 6, 271-317.

Sissakian, V. K. & Fouad, S. F. 2015. Geological map of Iraq, scale 1: 1000 000, 2012. Iraqi Bulletin of Geology and Mining, 11, 9-16.

Tao, Z. & Alves, T. M. 2019. Impacts of data sampling on the interpretation of normal fault propagation and segment linkage. Tectonophysics, 762, 79-96.