Seismic subsurface structure study to determine the actual depth of the Cretaceous succession.

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Abstract

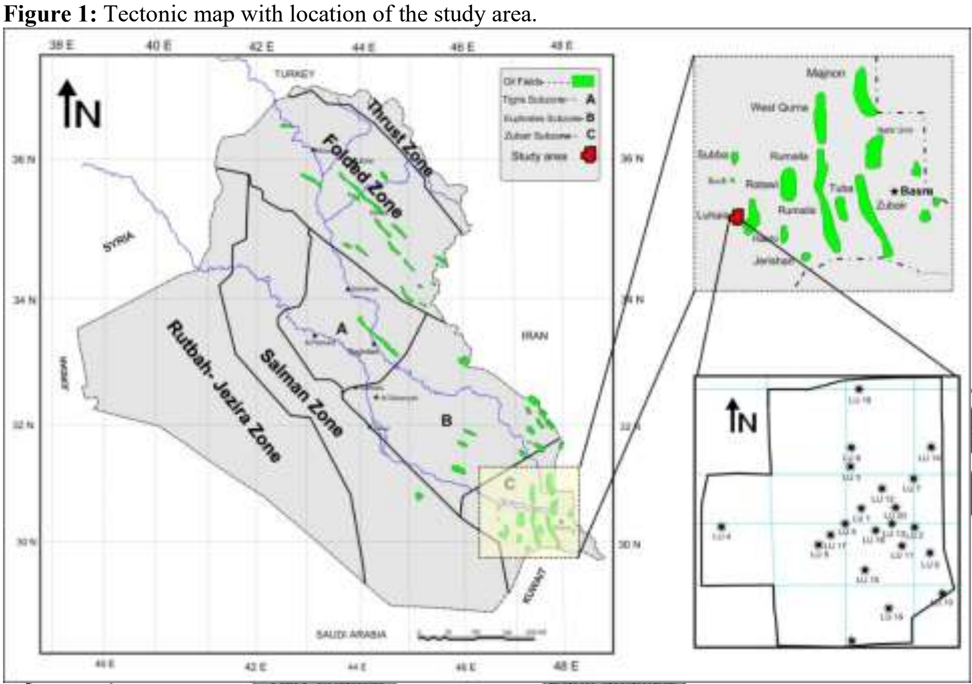
In this study, the technique of seismic attribute was applied on two-dimensional seismic sections in order to generate accurate depth map of Nhr-Umr Formation and to reveal the fault trend in Luhais oil field, southern Iraq. The Nhr-Umr Horizon was tracked depend on the check shot which is available only in two wells (Lu 2 and Lu 21).The importance of Nhr-Umr Formation is considered as the main reservoir of oil in this field . The time map of Nhr-Umr Horizon shows that there is a major irregular enclosure including above many minor enclosures. The depth conversion process was carried out by using different velocity models. The accurate model that gives less differences between the actual and estimated depth have been created to convert the time map into depth map. The depth map of Nhr-Umr Formation is more dense than the time map and shows irregular shape. The depth increase toward the northeastern part of the area reached to depth of 2550 m. whereas the depth is reduced in the crest of the structure reached to 2400 m. The differences between the time map and the depth map because of the horizontal variations of velocity in the field. The main trend of faults in this field is north-south.

Keywords: Seismic interpretation; Seismic attribute; Actual depth

1. Introduction

Luhais oilfield is located in southeastern of Iraq Figure (1). Nhr-Umr Formation age is belonging to Albain deposit and located in southern part of Iraq. Its includes black shale interbedded with sandstone (Bellen et al.1959). The depositional environment of this field includes mixture of ground, shallow marine, deltaic, and tidal environments with interspersed natural marine area (Al-Sayyab et al.1982). The present study aimed to use a type of seismic attribute as a tool to conclude geological features from seismic reflection data, its used to reveal hidden geological features such as to determine the faults in the current study. As well as provide a time map to show the lateral changes in the map in the time domain, these changes reflect the tectonic process that occur in the region, then convert the time map from the seismic record (time) to the depth measurements by velocity model, so these depth map will provide true subsurface structure. Figure (2) shows the workflow procedure of methodology in this study.

Figure 1: Tectonic map with location of the study area.



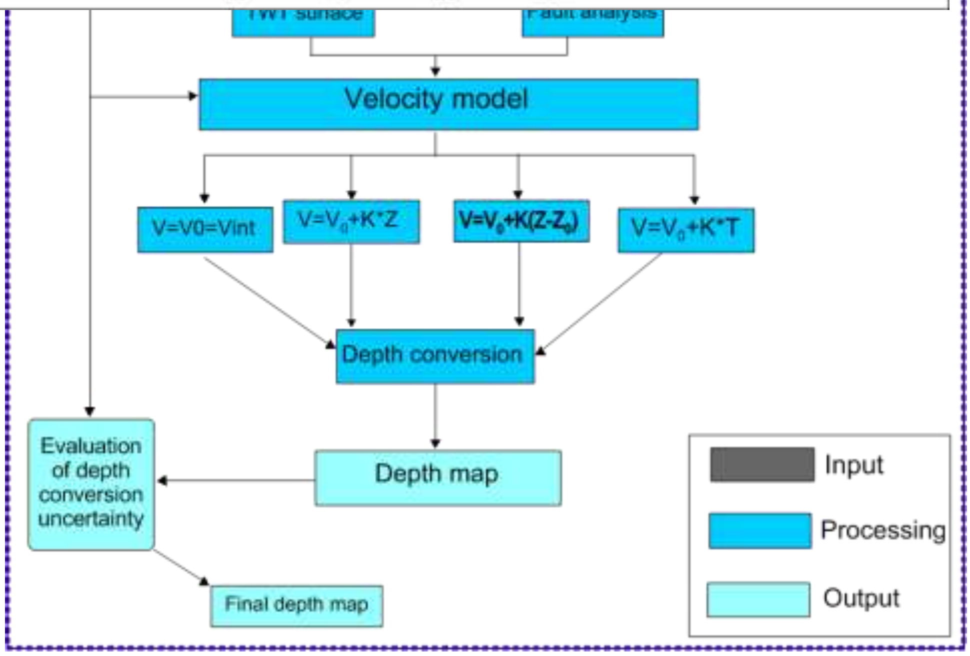


Figure 2: Workflow procedure display multi-velocity models that used in seismic interpretation depth conversion.

2. Geological Settings

Tectonically, the Luhais oilfield is located within the southern part of the Mesopotamian Basin in the Zubair subzone (unstable shelf), in, Figure (1). The Zubair subzone is surrounded by the Al-Batin transversal fault in the south and the Takhadid-Qurna transversal fault in the north (Aqrawi et al., 2010). The main subsurface structures types were founded in the Zubair subzone folds and salt domes that form most the oil fields (including Luhais oil field). Luhais

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oil field is considered as anticline fold structure with N-S direction (Jassim and Goff, 2006), The main trend for these structures is N–S. These folds are extended a hundreds of kilometers along and are separated by broader synclines (Jassim and Goff, 2006). Therefore, Luhais oil field is structurally anticline fold.

The area was uplifted as a result of the Hercynian deformation event that occurred from the Late Devonian to the Middle Permian. But subsequently subsided through Late Permian. Most of the oil fields in southern Iraq were produced because of the impact of collision between the Iranian plate to the north and east with Arabian Plate during Oligocene. Compressional forces changed the geometry of sedimentary sequences within the basins located along the northeastern edage of the Arabian Plate, including the Mesopotamian foreland basin, leading to the development of broad folds that formed major hydrocarbon traps.The Luhais oilfield generated along lineation developed during eruption of the Neoproterozoic–Cambrian (Infracambrian) Hormuz Salt dome (Husseini, et, 1988, Rad, et, 2008) that continued during Jurassic. Figure 3 shows the stratigraphic column of well Lu 12 that represents the stratigraphic column of southern Iraq.

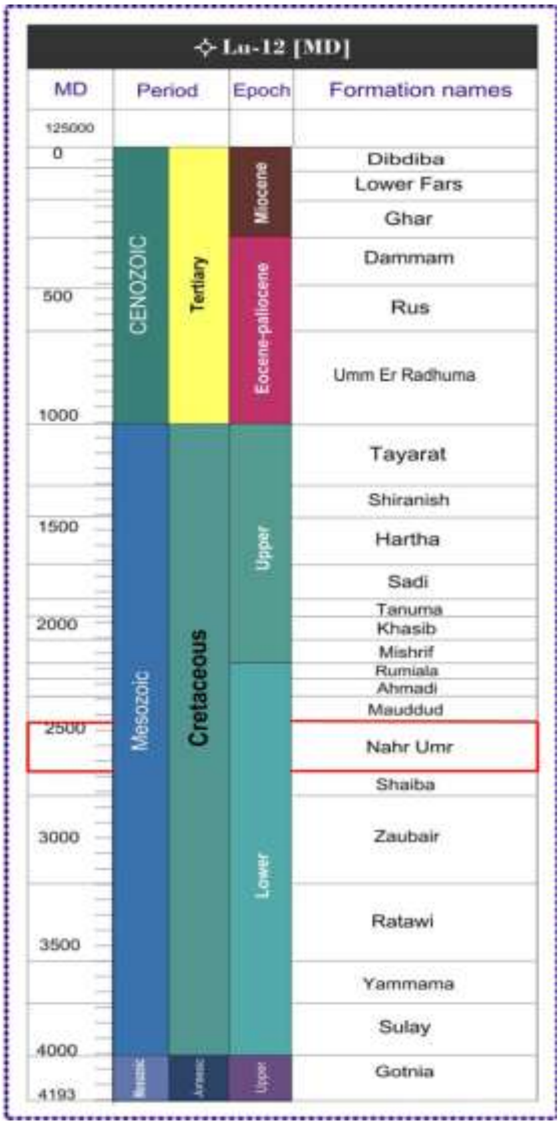


Figure 3: Geological stratigraphic column of Luhais oil field, well (Lu 12). Oil Exploration Company, 2012: Reinterpretation of previous seismic data of Suba-Luhais field, (A/1/217), (Arabic ref.).

2.1 Nhr-Umr Formation

Nhr-Umr Formation is one of productive clastic reservoirs in Luhais oil field, it is more than 360 m thick toward south part of the Mesopotamian and the Salman zones. The formation is more thickness in south Iraq and Kuwait (about 400 m), and in south of Baghdad (160 m). The two main depocenters in south and central Iraq correspond to areas which received clastics from the Rutba Uplift and the Arabian Shield.

The Nhr-Umr Formation consist of black shales interbedded with sandstone with lignite, amber, and pyrite (Ballen et al.,1959). In the Salman Zone, the proportion of sand in the formation was increased. The outcrops of Nhr-Umr Formation between Wadi Hauran in the north east and to the south west in highway between Rutba-Baghdad. The upper zone (11 m thick) consist of yellow to white sandstone with green sandy marl and reddish limestone.

The formation is overlain by the Mauddud Formation and overlies by Saggar Formation; the contact is taken at the base of a 2m thin-bedded limestone bed. The formation thickens towards the 50 km east of Rutba to 54 m, east from 22 m, 140 km east of Rutba. The bottom of the Nhr-Umr Formation is conformable and gradational according to (Bellen et al.,1959). Douban and Medhadi (1999) recognized a 6 Ma age break at the base of the Burgan Formation (Nhr-Umr equivalent) in Kuwait. However in the Butmah structure the Nhr-Umr Formation is disconformably overlain by the basal conglomerate of the Mushorah Formation. In Kuwait, the Nhr-Umr Formation is a horizontal equivalent of the Burgan Formation (Sharland et al., 1970). In southwestern Iran the formation passes into the shales and limestones of the Kazdhumi Formation (Furst, 1970). Figure (4): shows the thickness map of Nhr-Umr Formation.

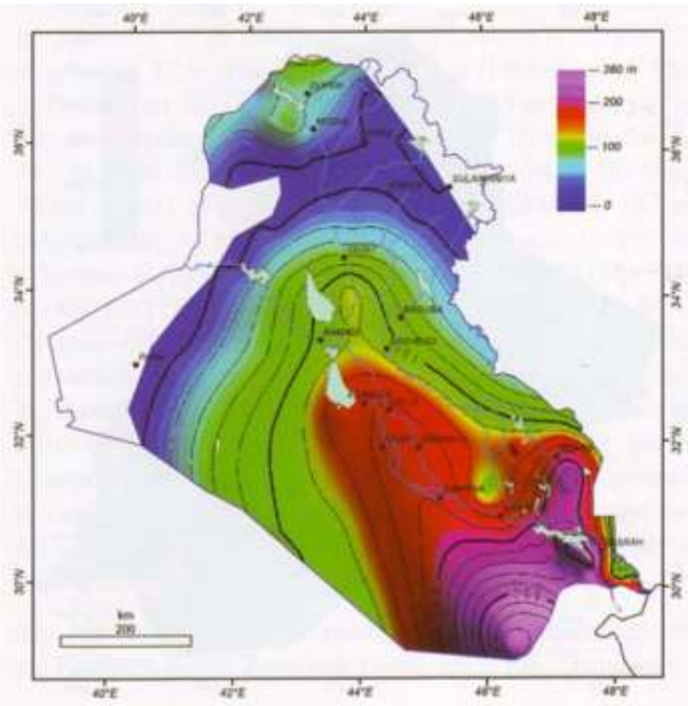


Figure 4: Thickness map of the Nhr-Umr Formation (with Rim Siltstone). (Jassim and Goff, 2006).

3. Database

The dataset available in current study includes Well data which include well tops, total vertical depth (TVD) of 21 well, and check-shot of only two wells (Lu 2 and Lu 21). Also Seismic data which include (10) tow-dimensional seismic lines distributed in study area and taken in different directions according to the design that considered in preplanning of survey these are (SL25, SL27, SL29, SL31, SL36, SL38, SL44, SL46, SL48, and SL50). Figure (5) shows the base map of the region.

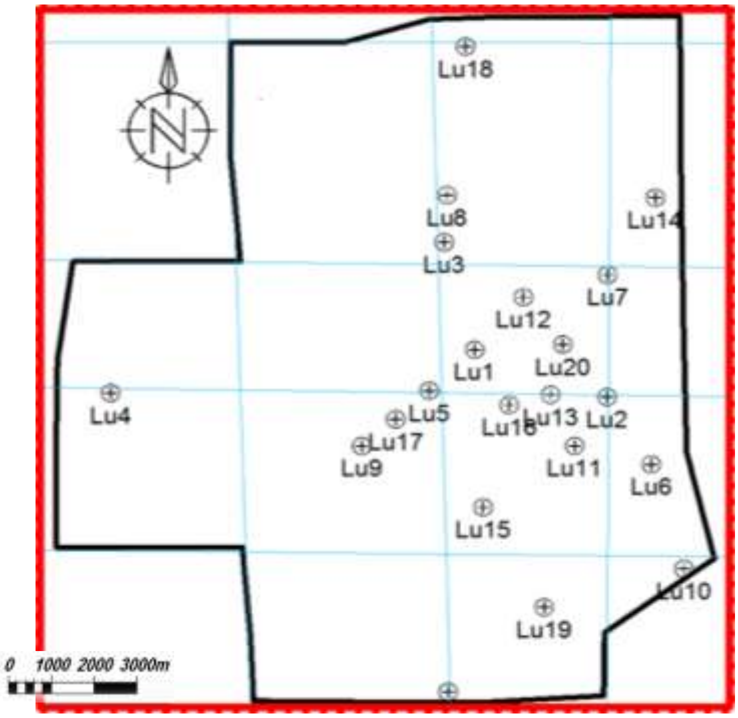


Figure 5: Base map of Luhais oilfield

4. Seismic Interpretation

The fault picking carried out before picked reflector to avoid errors in the interpretation. Fault with large displacement are obvious to recognized, but in current study the picked fault with low vertical displacement. Therefore, the seismic attribute (variance attribute) was applied to determine fault trend and geomorphology (Al-Khazraji, 2023). The variance attribute were generate with input-parameter control (vertical smooth 15, inline range 3, and crossline 3). Figure shows original and variance attribute 2D seismic section. After fault picking, the picking process of Nahr Umr Reflector started from known point at well location (Lu 2) and complete picking by looping from three points (known point) to unknown point to avoid mistie between the reflector. Two types pf picking were used in this interpretation which are manual picking and autotracking. The autotracking is more rapidly and accurately than manual picking. This mode of picking was used to track the reflector Nahr Umr Reflector in case the reflector with high amplitude and continuity where the manual picking was used in following cases: 1) in region with low signal-to-noise ratio 2) the picked reflector branch out two reflectors 3) sudden geological change as a result of fault and channel present.

The reflection geometry of Nahr Umr Reflector shows parallel to subparallel continuity with high to medium amplitude characteristics in study area. The seismic response of Nahr Umr Reflector is trough because the acoustic impedance of reflector (Nahr Umr Formation) decrease as compared with above (Mauded Formation).

4.1 Seismic Attributes Technique

Seismic event interpretation can be identifying through the use of numerous seismic attributes (White, 1991; Barnes, 2001), by determine similar patterns, and via quantifying identify properties. Seismic attribute is a lusty facet of reflection seismic method for oil exploration and finds widening uses, from anomaly identification to feature extraction to lithological prediction (Barnes, 2016). Geological features record structural, stratigraphic, and lithological features of seismic reflection data. Structural features involve dip, azimuth, discontinuity, and curvature. Stratigraphic features point out largely to 3D reflection styles as explained via the ideas of seismic stratigraphy. They involve consistency, reflection spacing, and thickness of the thin-bed. Lithological features predict density, fluid content, porosity, velocity, sand percent, impedance, and quality factor (Barnes. 2016).

In the current study Variance attribute was used to show faults more clearly than the seismic section, as shown in Figures (6, 7 and 8).

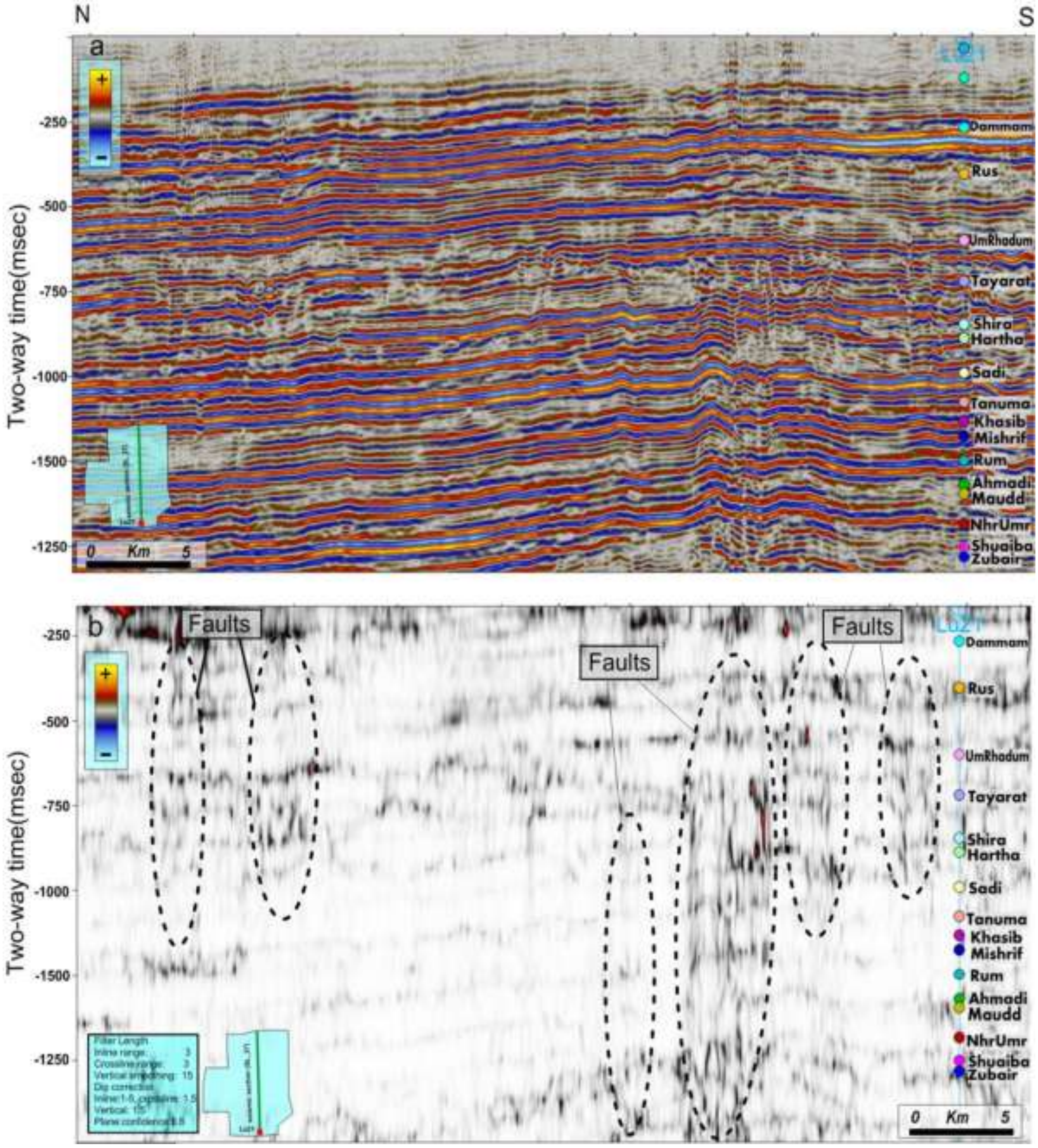


Figure 6: North-South 2D seismic section, a) original, b) variance attribute seismic section pass through Lu 21 well.

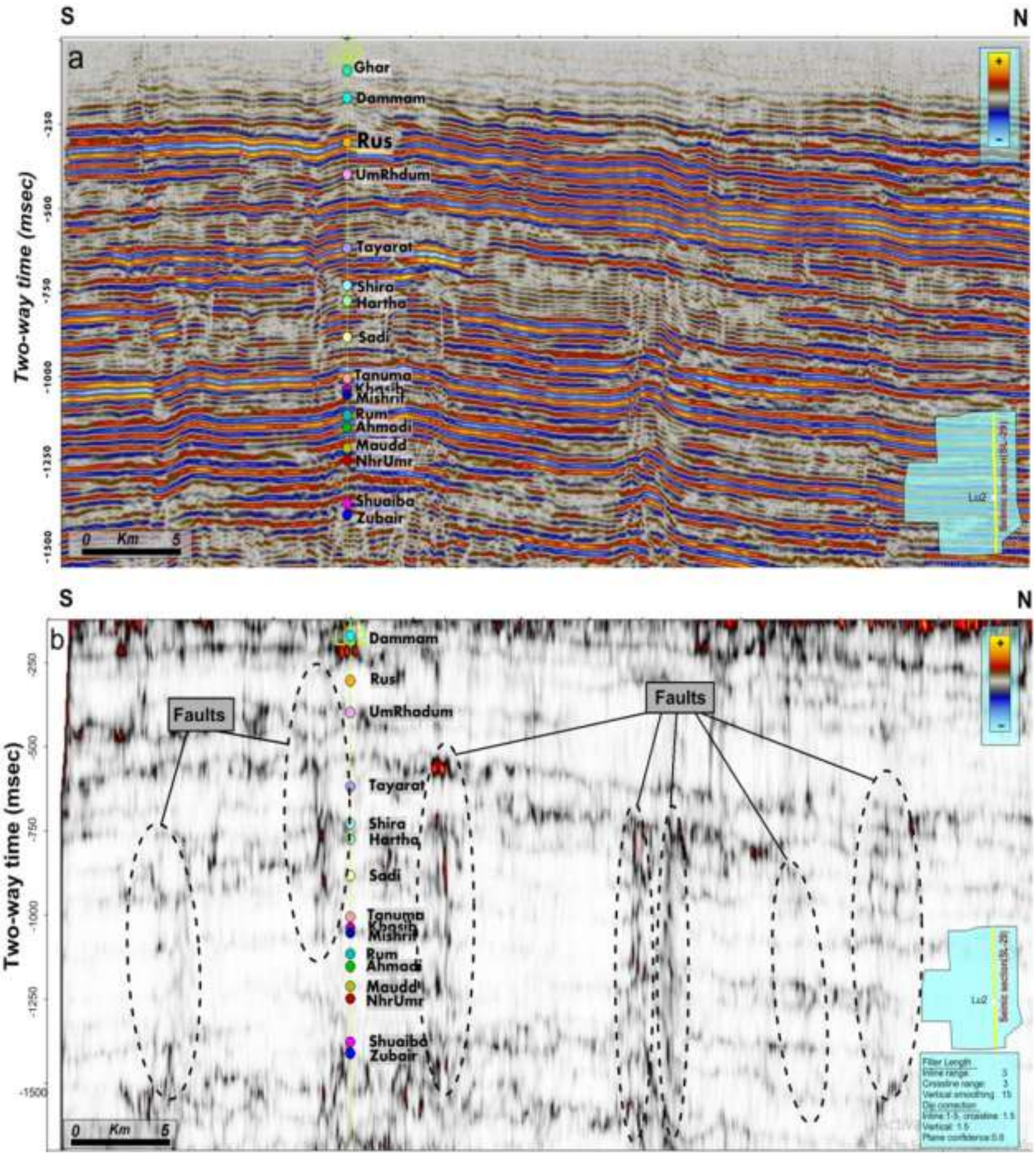


Figure 7: South-North 2D seismic section, a) original, b) Variance attribute seismic section pass through Lu 2 well.

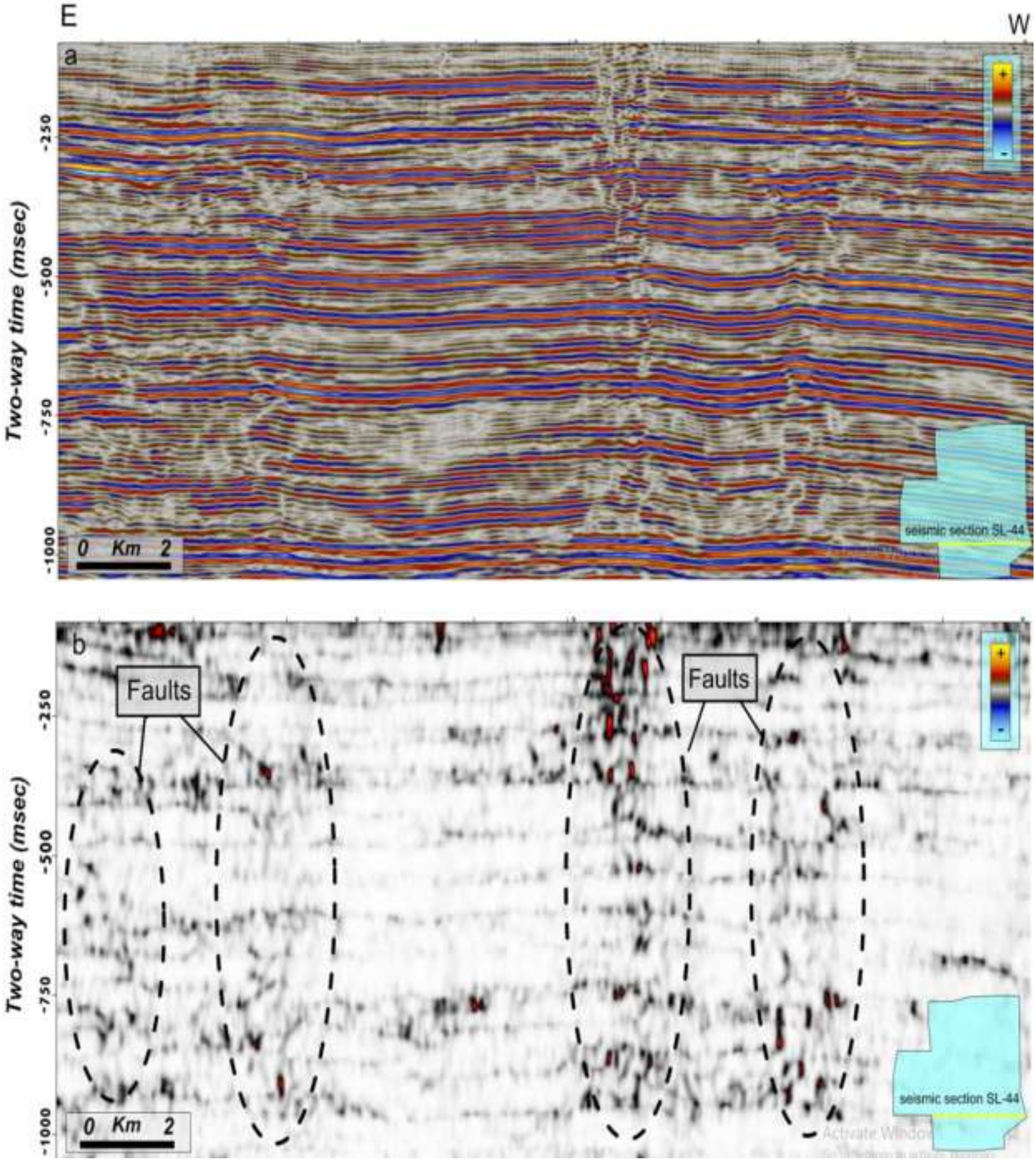


Figure 8: East-West 2D seismic section, a) original, b) Variance attribute seismic section.

4.2 Fault Picking

Faults are picked on the seismic section to delineate faults trend in the Luhais oil Field , some of these faults were not so obvious, therefore, can not to be explained more easily, this is; because faults with low displacement, therefore, the attribute technique was carried out to show them more clearly. As illustrates in Figure (9).

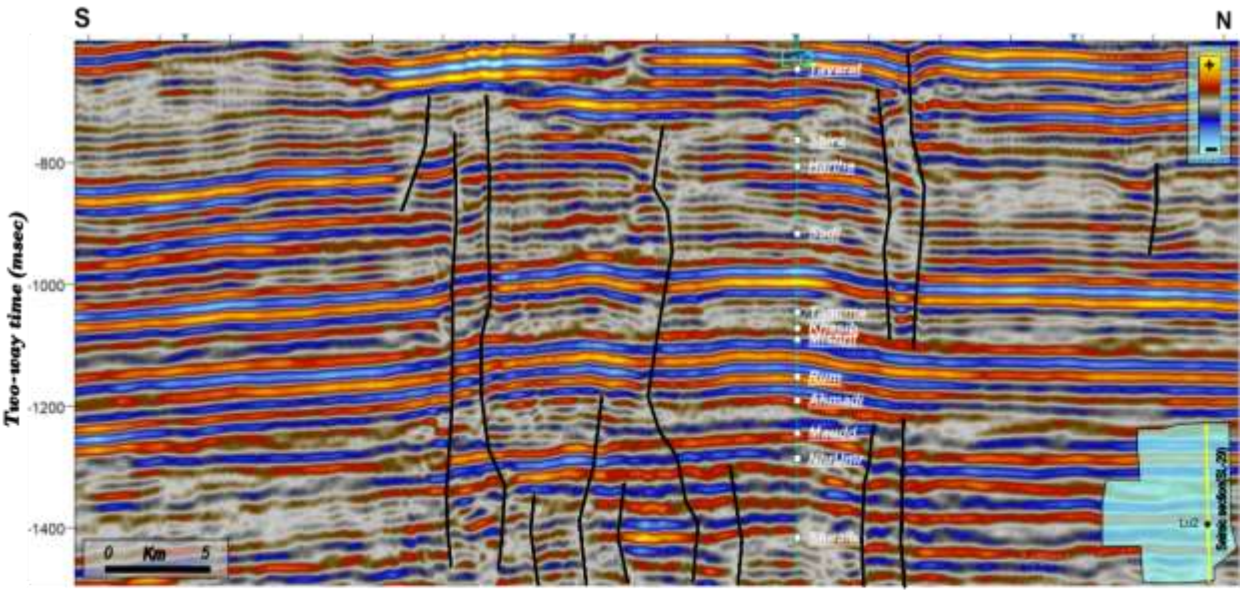


Figure 9: Fault picking on South-North 2D seismic section.

4.3 Horizon Picking

Horizon picking is the marking of the reflector on the seismic section in the time domain, where these reflector contains the changes that occurs to the reflector during and after sedimentation period from tectonic process that caused the geological structure such as faults, folds (anticline and syncline), and the nature of sedimentation of the sediment materials that give the stratigraphic shapes. Horizon picking gives information about the nature of sedimentation, stratigraphic, and structural discontinuities.

Lu-2 and Lu-21 wells were used to track the reflector of Nhr-Umr Formation, The reflector has good continuity (high amplitude) in the seismic sections were it was picked automatically by using (2D auto track), except in some sections the reflector was very weak (low amplitude), as it required to be picked manually especially in faulted zones. As shown in Figure (10):

Figure 10: Horizon picking on South-North 2D seismic section pass through Lu2 well.

5.1 Time Map of Nhr-Umr Horizon

Interpreted reflection times are regularly mapped along seismic lines to produce a TWT map that describes the subsurface structural geometry. Seismic data are initially recorded in the time domain, clarify the TWT of seismic waves from the source to the reflector and back to the receiver. In this study Two TWT maps are created for the top of Nur-Umr Formation (contour interval 15 ms) as shown in (Fig. 11)

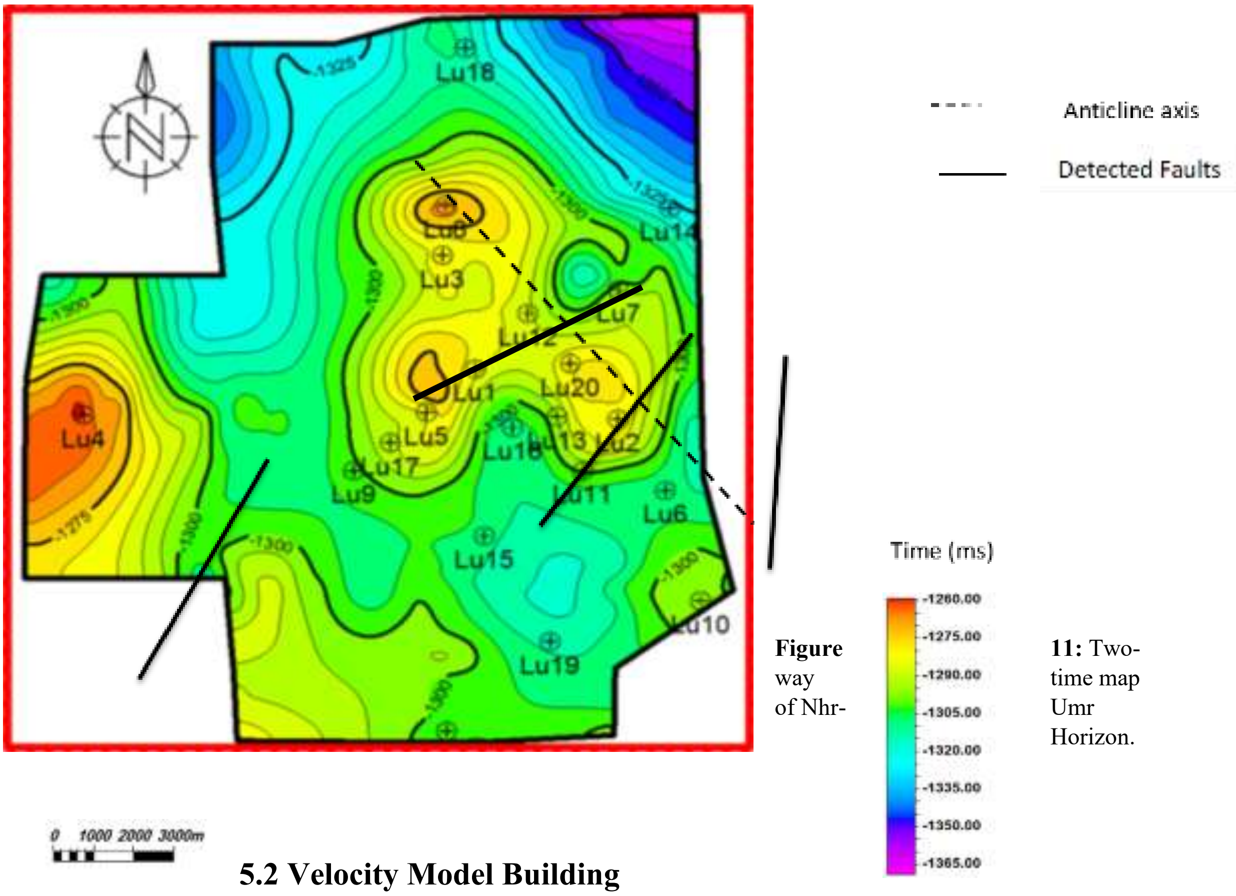


Figure 11: Two-way time map of Nhr-Umr Horizon.

5.2 Velocity Model Building

Velocity model is a link to convert the map from time domain to depth domain. The data required to generate the velocity model are well tops readings of 21 wells of Nhr-Umr Formation. Also generate a time-depth relationship (TDR) from the information of check-shot which is available only in two wells (Lu2 and Lu21), and that is one of the benefits of check-shot, is that builds a time-depth relationship through which to build a velocity model.

Four velocity models were made of Nhr-Umr Formation by using different equations, as shown in (Table 1), which are:

$V=V_0=V_{int}$………….... (1)

$V = V_0 + K * Z$ ……….. (2)

$V = V_0 + K (Z- Z_0)$ ………. (3)

$V = V_0 + K * T$ ……………. (4)

Where:

V_0 : The initial velocity at the top of the surface

K: The rate of velocity value change with increasing depth

Z: The actual depth

T: The seismic interpreted time

The velocity model (1) of equation $V=V_0=V_{int}$ was chosen as dependent model to the convert the time map to the depth domain, because it gives the most accurate result and the least differences between the actual and estimated depth, As shown in (Table 1).

Table (1): Geostatistical analysis of four velocity models were used in current study.

Well	Actual depth	Estimated depth (V.M 1)	Residual	Estimated depth(V.M 2)	Residual	Estimated depth(V.M 3)	Residual	Estimated depth(V.M 4)	Residual
Lu4	-2495.4	-2358.05	-137.35	-2041.99	-453.41	-2041.99	-453.41	-2265.43	-229.97
Lu15	-2479.5	-2461.69	-17.81	-2118.65	-360.85	-2118.65	-360.85	-2360.75	-118.75
Lu8	-2472	-2382.43	-89.57	-2060.11	-411.89	-2060.11	-411.89	-2287.88	-184.12
Lu11	-2475.3	-2442.18	-33.12	-2104.3	-371	-2104.3	-371	-2342.83	-132.47
Lu20	-2490	-2408.73	-81.27	-2079.6	-410.4	-2079.6	-410.4	-2312.09	-177.91
Lu21	-2619	-2446	-173	-2107.11	-511.89	-2107.11	-511.89	-2346.34	-272.66
Lu6	-2481	-2456.17	-24.83	-2114.59	-366.41	-2114.59	-366.41	-2355.68	-125.32
Lu7	-2490.6	-2425.96	-64.64	-2092.34	-398.26	-2092.34	-398.26	-2327.93	-162.67
Lu13	-2490.8	-2423.68	-67.12	-2090.65	-400.15	-2090.65	-400.15	-2325.83	-164.97
Lu12	-2491	-2417.77	-73.23	-2086.28	-404.72	-2086.28	-404.72	-2320.39	-170.61
Lu1	-2495.4	-2410.82	-71.18	-2081.15	-400.85	-2081.15	-400.85	-2314.01	-167.99
Lu3	-2480	-2409.5	-70.5	-2080.17	-399.83	-2080.17	-399.83	-2312.79	-167.21
Lu9	-2484.2	-2445.17	-39.03	-2106.5	-377.7	-2106.5	-377.7	-2345.58	-138.62
Lu14	-2506.7	-2476.32	-30.38	-2129.39	-377.31	-2129.39	-377.31	-2374.17	-132.53
Lu16	-2476.7	-2456.65	-20.05	-2114.95	-361.75	-2114.95	-361.75	-2356.12	-120.58
Lu17	-2482.6	-2426.63	-55.97	-2092.83	-389.77	-2092.83	-389.77	-2328.54	-154.06
Lu5	-2487	-2415.21	-71.79	-2084.39	-402.61	-2084.39	-402.61	-2318.04	-168.96
Lu19	-2516.5	-2465.29	-51.21	-2121.3	-395.2	-2121.3	-395.2	-2364.05	-152.45
Lu2	-2473.5	-2405.79	-67.71	-2077.42	-396.08	-2077.42	-396.08	-2309.37	-164.13
Lu18	-2478.4	-2466.76	-11.64	-2122.38	-356.02	-2122.38	-356.02	-2365.4	-113
Lu10	-2505.7	-2435.14	-70.56	-2099.11	-406.59	-2099.11	-406.59	-2336.36	-169.34

5.3 Depth Map of Nhr-Umr Formation

Depth conversion is applied to convert the time structure map to depth map, the importance of the depth map is summarized to give the true geometric dimensions of the field, since the time map does not give the true dimensions of the field. In addition, the process of drilling wells is in the depth domain, so it requires to make the depth map. The depth map of Nhr-Umr Formation is obtained by using velocity model (1), as shown in Figure (12).It is denser than the time map and its show more details of the structure, which it is a major irregular anticline with minor enclosures in the central part of the study area. The range of value of this map is (-2370_ -2550 m), and the depth is increases toward the northeastern part of the study area, reaches 2550 m.

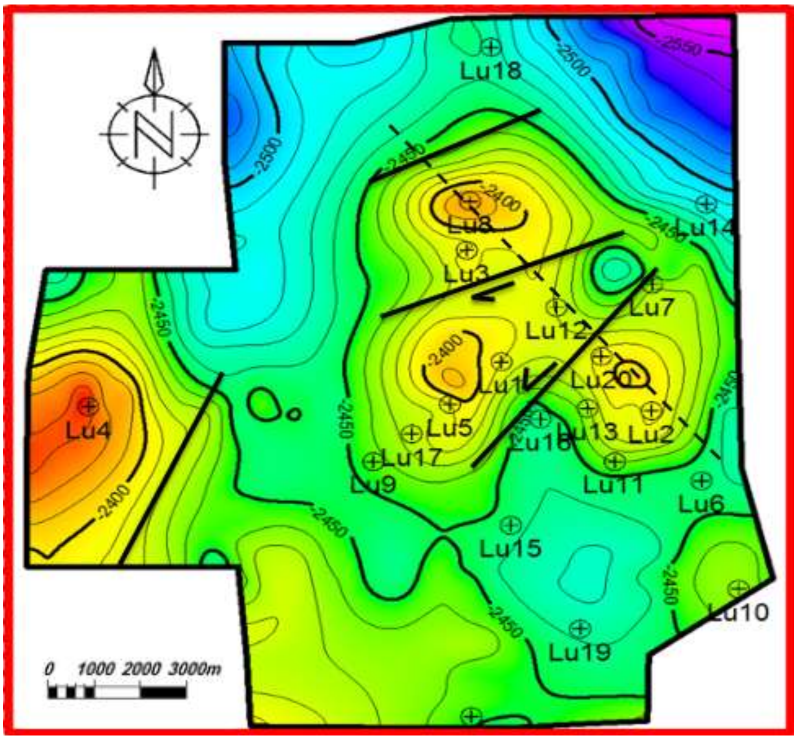
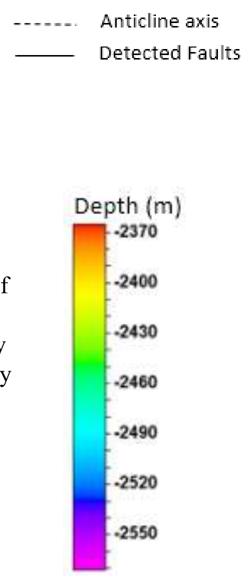


Figure 12: Depth map of Nhr-Umr Formation by using velocity model (1).



6. CONCLUSIONS

In the current study, the seismic attribute (variance) was applied and proved to be an effective tool for identifying and tracking faults on seismic sections. Interpretation of the seismic sections combined with seismic attribute analysis revealed the presence of numerous normal faults within the study area, most of which are characterized by low displacement. Based on both time and depth maps, the general fault trend was determined to be predominantly north–south. The derived two-way travel time (TWT) and depth maps were further utilized to delineate fault locations by analyzing their extensions and orientations. Two main faults were identified cutting the Luhais oil field anticline with a NE–SW strike. These faults are interpreted as strike-slip faults, and the resulting structural configuration exhibits three lobes (enclosures), suggesting that sub-structural deformation may have contributed to the formation of a hydrocarbon trap within the deeper sedimentary formations. Notably, the extension direction of these faults corresponds to the regional tectonic stress direction acting from southwest to northeast, associated with the collision of the Eurasian Plate with the Arabian Plate. The time map of the Nhr-Umr horizon displays a major irregular enclosure with several smaller closures concentrated in the central part of the study area. Furthermore, this study presents a new structural depth map for the Nhr-Umr Formation generated using different velocity models, where velocity model (1) was found to be the most reliable, producing the smallest difference between actual and estimated depths. The depth map reveals more structural detail than the time map, as it represents the true geometric dimensions of the field and illustrates a major elliptical anticline with minor closures in the central area. This anticline may have been subjected to prolonged weathering or may represent an unconformity surface between the Nhr-Umr Formation and the overlying formation. The fold axis, identified from both time and depth maps, trends in a northwest–southeast direction. Finally, the minimal difference observed between the TWT and depth maps indicates low lateral velocity variation across the study area.

Conflicts of interest

There are no conflicts to declare.

Acknowledgements

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