Structural study of Nahr Umr Oil Field in Southern Iraq

Manal Shakir Al-kubaisi; Aymen Adil Lazim.

Abstract

Nahr Umr oil field is one of the important productive southern Iraqi oil fields. This study focuses on the type of fold and faults of the Nahr Umr oil field. A structural analysis (geometric and genetic analyses) performed to identify its type, origin and to find its relevance to main regional tectonic events. The structural classifications employed well and geophysical data through using structure contour maps, cross sections, and seismic section.

The structural analysis inferred that fold of Nahr Umr oil field classified as antiform, upright, non-plunge, gentle, supratenous, dome feature, and asymmetrical. The limbs are unequal whereas the length of left limb shorter than the right limb and its dip is greater than right limb. In addition, the thickness of crest is less than the thickness of limbs. Pattern of faults classified as compound, parallel, conjugates and radial with graben structure and these faults concentrated on crest of fold. The fold axis is almost N-S at early cretaceous and then clearly turns to NW-SE and this may due to counterclockwise rotation of Arabian plate. Geophysical interpretations and results of structural analysis stated that Nahr Umr oil field formed by three combined forces which are tectonic movements, reactivated basement, and salt structures.

Keywords: Nahr Umr field, structural analysis, salt structure, basement fault, tectonic movement.

1. Introduction

Nahr Umr oil field is located about 25 km north north-west of Basra city, southern Iraq between latitudes (30° 35' - 30° 50') and longitudes (47° 45' – 47° 45'), south of Majnoon field and eastern Zubair field and separated from each of them by saddle and the Shat Alarab river divided it to two parts figure(1). It is thought that the structure is a part of the Majnoon oil field but the geological studies confirmed that they are separated by a saddle (Al-Ubaidi 1996). The Oil is present in many formations, which are from bottom to top: Yamama and Zubair Formations (Early Cretaceous), Nahr Umr, Mishrif Formations (Middle Cretaceous), Sadi, Khasib (Late Cretaceous). Ghar, Fatha (or Lower Fars) Formations (Early-Middle Miocene).The best reservoirs are Yamama, Zubair, and Mishrif formations (Braspetro 1981). This study aimed to show the structural picture of Nahr structure and its relevance to regional tectonic forces through achieving structural analysis. This analysis included two types, geometrical and genetic analysis. Geometrical analysis studies the geometrical elements of a structure (linear and planar elements). While, genetic analysis employed the geophysics interpretations to determine the causes, type and the origin of Nahr Umr oil field.

2. Geologic Setting:

According to Buday and Jassim (1987) tectonic divisions, Nahr Umr oil field lies in Mesopotamian Zone within Unstable Shelf of Arabian Platform. According to Numan (1997and 2000), it lies in sagged basin within the Mesopotamian zone of the qusiplatform foreland belt of the Arabian plate. Nahr Umr oil field is located in Zubair subzone of the Mesopotamian zone, whereas the structures of this subzone controlled by the basement structures and Infracambrian salt (Jassim and Goff 2006). Al-Sakani (1995) stated that Nahr Umr oil field belongs to the Unstable Shelf, and the factors of instability are basement faults, salt structures, and Alpine Orogenic Movements and these factors worked together to produce anticline subsurface structures southern Iraq. Zubair subzone bounded by basement faults which are Takhadid-Qurna Transversal fault from north and southern boundary is Al Batin fault (Jassim and Goff, 2006). The negative gravity anomaly of the primary Zubair subzone structures proved the presence of deep-seated Infracambrian salt rocks (Karim, 1989 and1993; Jassim and Goff 2006; Karim et al. 2010).

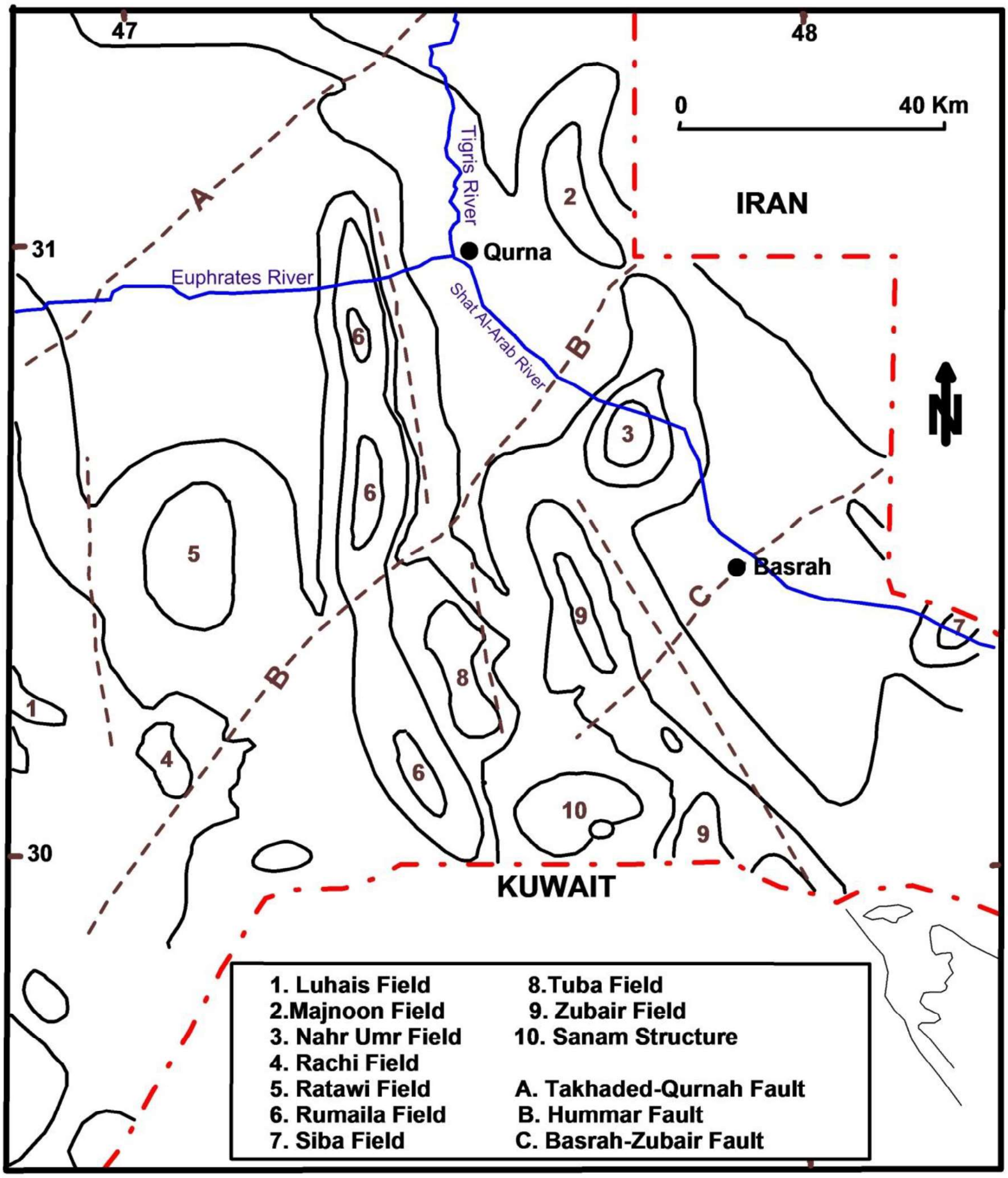

Fig.(1): The location of Nahr Umr oil field with respect to the surrounding major structure at the depth (4000m), Basra city with some of basement faults in Mesopotamian zone. Modified from Al-Mutury and Alasdi(2007).

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3. Geometric Analysis of Folds for the Nahr Umr field

Nahr Umr oil field is a subsurface structure, therefore the study made five structural and five cross sections (perpendicular on fold axis) for Ratawi Formation (Lower Cretaceous), Muddud Formation (Middle Cretaceous), Sadi Formation, Tayarat Formation (Upper Cretaceous), and Dammam Formation (Tertiary) based on well data and used one structural map constructed by geophysical data, in addition to one seismic section. Values of dip and dip direction, and also the *plunge angle data are gained by using simple equation (Tan of dip angle) = opposite (contour interval) / adjacent (contour spacing) (Groshon 2006), and these values are calculated from the contour maps for the formations of Nahr Umr oil field figure(2).

There are many classifications of the folds; each one uses certain geometric parameters of the fold. According to the essential parameters of the fold this study will classify the Nahr Umr oil field depending on (1) Fold facing, (2) Fold orientation (dip of axial surface, plunge of hinge line, and symmetry of fold), (3) Fold shape in profile plane (interlimb angle and variation in thickness), (4) Fold dimensions, and (5) Fold curvature analysis.

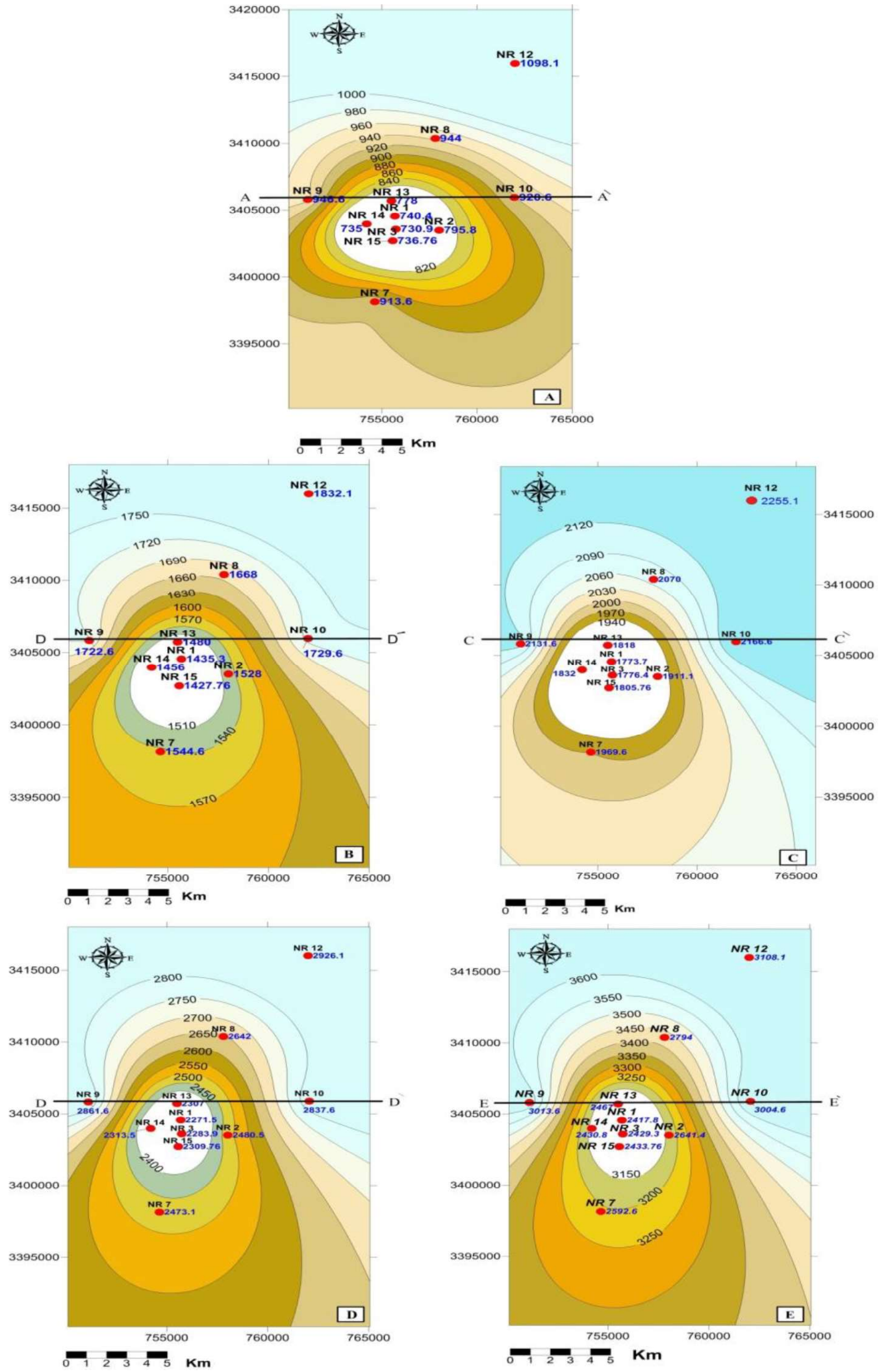


Fig. (2): Structure contour maps. The red dots are the wells, and the blue numbers are the depth of these wells in meters.(A) Dammam Fm.the contour interval is 20m.A-A'is a cross section/(B) Tayarat Fm.the contour interval is 30m.B-B'is a cross section.(C)Sadi Fm.the contour interval is 30m.C-C'is a cross section.(D) Mauddud Fm.the contour interval is 50m.B-B' is a cross section.(E)Ratawi FGm.the contour intervalis 50 m. E-E' is a cross section.

Table(1): data of geometric classification of Nahr Umr field.

Age	Formation	Dip and Dip direction		Dip of Axial Surface	Plunge Angles		Interlimb Angle	*R*	K
		Western Limb	Eastern Limb		South Plunge	North Plunge			
Tertiary	**Dammam**	2°/244°	1°/64°	90°/154°	2º	2º	177º	0.75	9
Upper Cretaceous	**Tayarat**	3°/270°	2°/90°	90°/180°	1º	3º	175º	0.96	14
Upper Cretaceous	**Sadi**	4°/270°	3°/90°	90°/180°	1º	2º	173 º	0.44	24
Middle Cretaceous	**Muddud**	8°/270°	5°/90°	90°/180°	1º	6º	167º	0.93	14
Lower Cretaceous	**Ratawi**	9°/270°	5°/90°	90°/180°	2º	5º	166º	NIL	18

According to direction of a closure, which is obtain from the direction of axial surface direction, there are three kinds of folds which are antiforms (close upwards), synforms (close downwards), and neutral (close in a horizontal direction) (Lisle 2004). The cross section and the values of dip and dip direction of the Nahr Umr oil field show that the structure is an antiform structure table (1).

3.2. Fold Orientation

3.2.1. According to the dip of axial surface:

An axial surface defined as a surface that connects fold hinge lines (Groshong 2006). According to dips of Axial Surface, folds are classified to three types (Recumbent, Inclined, and Upright). The average dips of axial surface of Nahr Umr oil field is 90° are shown in table (1) and these value referred to that the structure is upright fold.

3.2.2. According to the plunge of hinge line

Hinge line is a line included the maximum curvature on the surface of a layer (Groshong 2006). According to the plunge of hinge line a fold can be classify to five types (Lisle 2004). The values of plunge of the hinge line of Nahr Umr were calculated for the south and north ends of the structure. These values are ranged from 1° to 5° as listed in table (1). Therefore, Nahr Umr oil field is classified as a horizontal fold or non-plunged fold.

3.2.3. According to the symmetry of fold

The symmetry of a fold can be determined by the relationship between lengths of limbs. Symmetrical folds have limbs of equal length and asymmetrical folds have unequal limbs (Barnes and Lisle 2004). The cross section confirmed that Nahr Umr oil field is asymmetrical structure because the western limb is shorter than eastern limb figure (3).

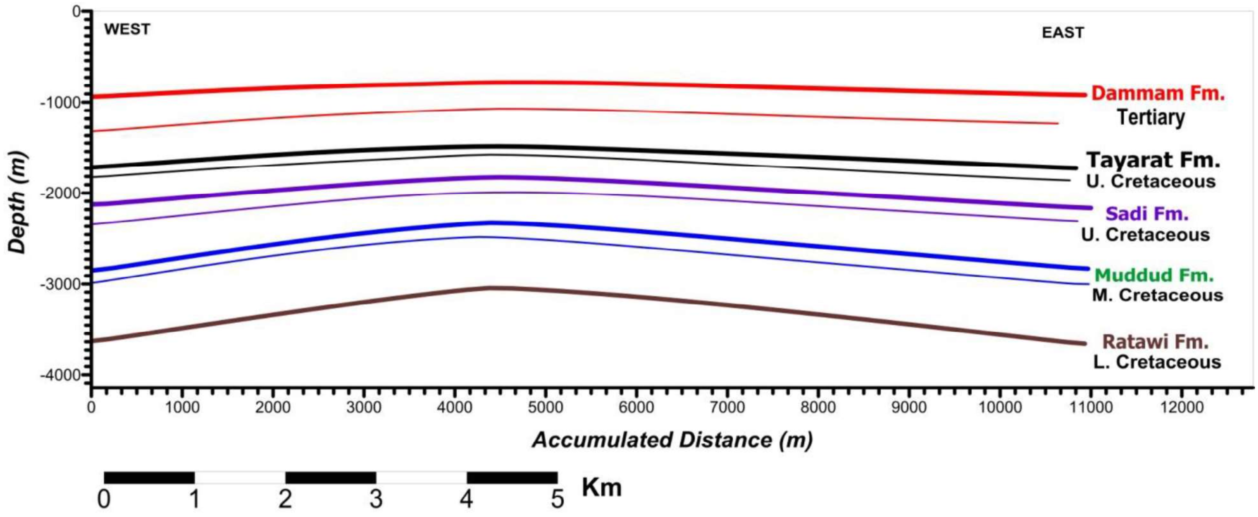


Fig.(3)An East-West cross section of Nahr Umr runs through NR9,NR10and NR13 wells.it shows the top five formations that accumulated from the time of L.Cretaceous to tertiary. The thickness of these formations at the crest of Nahr Umr is less than them in the limb.

3.3. Fold shape in profile plane

The plane taken perpendicular to the hinge line is called the profile plane of a fold (Van der Pluijm and Marshak 2004). It used two parameters: the interlimb angle and variation in thickness.

3.3.1. According to the interlimb angle

The angle between the limbs of a fold is called the interlimb angle (Fleuty 1964). The values of interlimb angle can be obtained through the values of dips of the formations instantly or via using Geocalculator software. Table(1) show that the interlimb angle of the Nahr Umr oil field is ranging between 166° (Ratawi Formation.) to 177° (Dammam Formation.). These values indicated that the Nahr Umr oil field is a gentle fold and stated the effect of folding deceased toward the recent formations.

3.3.2. According to the variation in thickness

Bhattacharya (2005) used axial angle and thickness ratio to classify folds. The thickness ratio (R) is ratio between the hinge thickness and the limb thickness. The R values of Nahr Umr oil field are less than 1 therefore Nahr Umr oil field classified as supratenuous fold. The thickness of limb is greater than crest and this due to the sedimentation was coinciding with folding as Bhattacharya (2005) stated. The study calculates the values of thickness ratio for all studied formations except Ratawi Formation because there is not sufficient well data for the formations below it.

3.4. Fold dimensions

This classification is according to the ratio between the lengths (L) to width (W) of the folds relative to same layer boundary. It has three types (Jaroszewski 1984): Linear fold ($L/W > 5$), Brachy fold ($5 > L/W > 2$), and Domes and Basins fold ($L/W < 2$). Al-Ansari (1998) reported that the length of the Nahr Umr oil field is 40 km, and the width is 25 km, therefore it is belong to domes and basins fold.

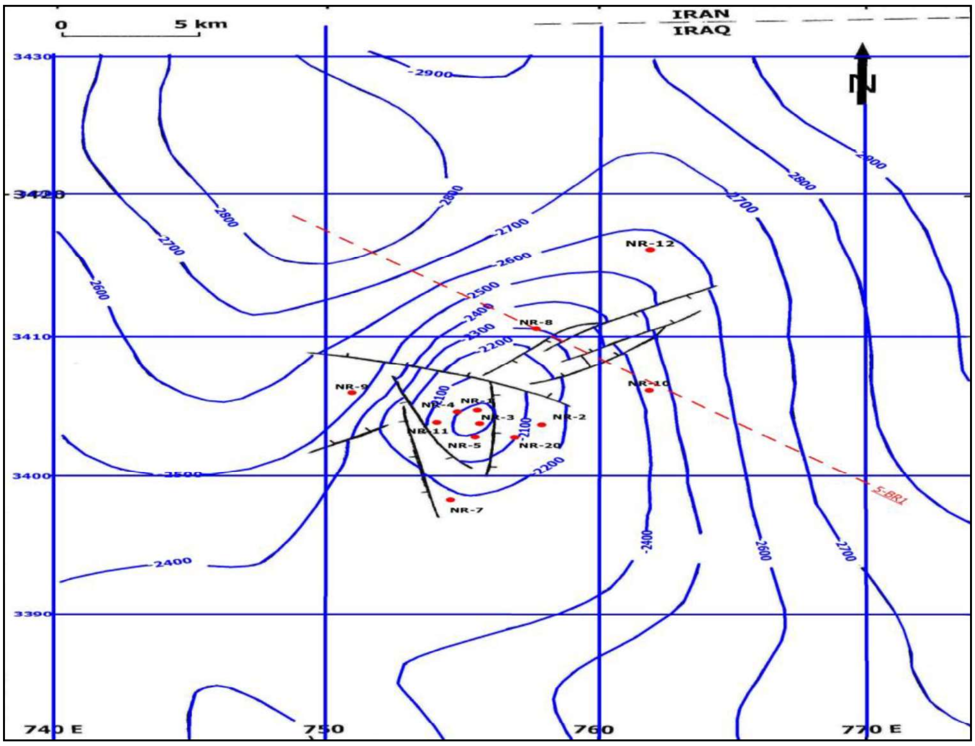
3.5. Fold Curvature

According to Masaferro (2003) and Lisle (1994), Curvature analysis is a method used the orientations and values of two perpendicular principal curvatures, which is the maximum curvature (K1) or (Kmax) and minimum curvature (K2) or (Kmin) in the principal directions. In addition, the contour pattern and the signs of K_1 and K_2 can use as an indication to a structure type. Whereas, if K (K1*K2) more than zero with positive sign, and the contour pattern. Nahr Umr oil field belongs to dome and basin pattern because the positive sign of K values ($K>0$) (table 1) and according to its contour line style figures (2 ، 4).

4. Classification of the faults:

4.1. Classification of Fault according to their pattern in map view

According to Van der Pluijm and Marshak (2004) the fault array defines as a group of related faults. The type of fault array determined according to the orientation and relationship of the faults array with respect to one another along strike. Nahr Umr oil field has two types of the fault arrays, parallel and conjugate faults figure (4).



Firig(4)Structure contour map on the top of mishrif formation shows the parallels, conjugate,and radial normal faults concentrated on the crest of Nahr Umr field. The dashed line is seismic line (5-BRI), modified from (Braspetro,1982).

4.2. Classification of Fault patterns related to Salt Structure

As mentioned before, a gravity anomaly associated with Nahr Umr may be related to salt structure beneath the structure and surrounding area. Braunstein and O'Brien (1968); Halbouty

(1979) they identify the typical faults over or adjacent to salt dome and according to these fault Nahr Umr faults can be classified as compound offset. In addition, the geophysical data confirmed the presence of graben structure over the crest of the structure figure (5).

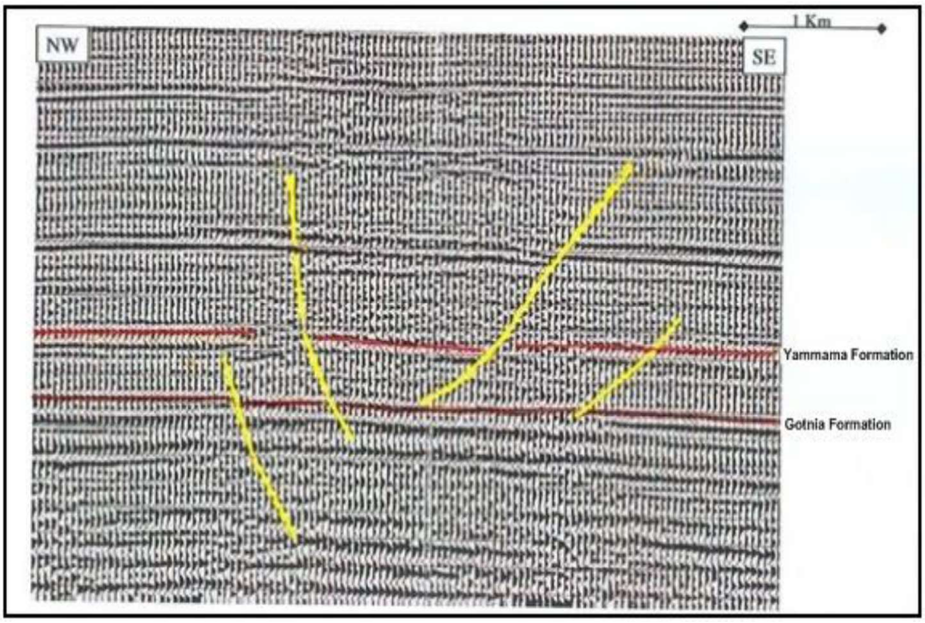


Fig. (5)Seismic section(5-BRI) shows graben Nahr Umr field , (Total fina Elf Co.2001).

4.3. Normal Fault patterns over to dome structure

Billings (1972) showed that normal faults are the typical faults broken sedimentary rocks on the top of the dome. These faults usually are radial or parallel patterns with obvious a graben structure over a dome. The patterns of radial and parallel faults and graben structure are so clear above the crest of Nahr Umr oil field figures (4 ، 5).

5. Genetic analysis of the Nahr Umr field

Geophysical Interpretations referred to three combined main forces are reactivated basement faults, salt structures, and Alpine Orogenic movements worked together to forming Nahr Umr field.

5.1. Geophysical Interpretations

Positive and negative gravity and magnetic residual are associated with anticlines structures southern Iraq. Negative gravity could be as a result of deep-seated salt beds of Infra-Cambrian salt beds, while positive gravity referred to basement uplift (Karim 1989 and1993; Jassim and Goff, 2006; Karim et al 2010). Thus, Nahr Umr oil field could be a result of the vertical movement of basement during the Late M. Cretaceous and deep-seated salt rocks (Karim 1993 and 1989; and Karim et al 2010.).

5.2. Role of basement rocks:

The basement rocks are continental crustal rocks belong to the northeastern margin of the Afro-Arabian Plate. Basement structures have considerably controlled distribution of sediment deposition and subsequent structural growth in Iraq (Numan 1997 and Ahlbrandt et al 2000).

According to Hijab and Al-Dabbas (2000) the tectonic evolution of Iraq has passed through two phases which are rifting phase (Permian- Upper Jurassic) and compression phase (Upper Jurassic-Recent). The geologic features that associated with rifting phase at divergent plate boundaries are tensional stress, block listric normal faulting, and basaltic volcanism. Whereas, the geologic features associated with compression phase at convergent plate boundaries are compression stress, reactivate preexisting listric faulting surface and reverse its prior direction movement, and volcanic actions in one side of rifted zone (Al-Mutury and Al-Asdi 2007).

The reactivation of preexisting faults by a reversal of slip direction is called tectonic inversion. This inversion has converted the former normal faults to reverse faults. Consequently, the sediment of rift or passive margin will transfer to up (Van der Pluijm and Marshak 2004), as shown in tectonic model of Nahr Umr oil field figure (6). The basement movement (basement uplift) makes big influence in the sedimentary cover of the Arabian plate (included the study area) and form the subsurface structures (Aqrawi, 1998; Ahlbrandt et al 2000; Al-Husseini 2000).

5.3. Role of salt structure

Geophysical evidences proved to the existence of salt rocks below Nahr Umr oil field and it may have a major role in forming the structure (Karim 1993 and 1989; Karim, et. al 2010). This salt may the thick bed of Infracambrian Hormuz Salt Basin, which surrounds the area of the southern Arabian Gulf (Ahlbrandt et al 2000; Al-Husseini 2000). Van der Pluijm and Marshak (2004) outlined the mechanism of salt structure to three mechanisms (1) Density inversion, (2) Differential loading, and (3) Gravity spreading. These mechanisms and buoyancy force are worked together to drive salt up through the overlying layers until it arrives level of neutral buoyancy.

Arching and thinning of the strata above the diapirs are derived by extensional tectonic (Park 1997). This leads to the forming normal faults over the tops of the domes (Jackson and Talbot 1986; Park 1997; Rowan et al 1999; Stover et al 2001; Volozh et al 2003; Van der Pluijm and Marshak 2004). These faults are may be radial (Billings 1972; Rowan et al 1999; Yin et al 2009) or parallel and tend to form grabens (Billings, 1972; Rowan et al 1999) or half graben (Stover et al 2001; Volozh et al 2003) or conjugate normal faults (Van der Pluijm and Marshak 2004) Geometric analysis of fault and fold confirmed that most of these structures present in Nahr Umr field.

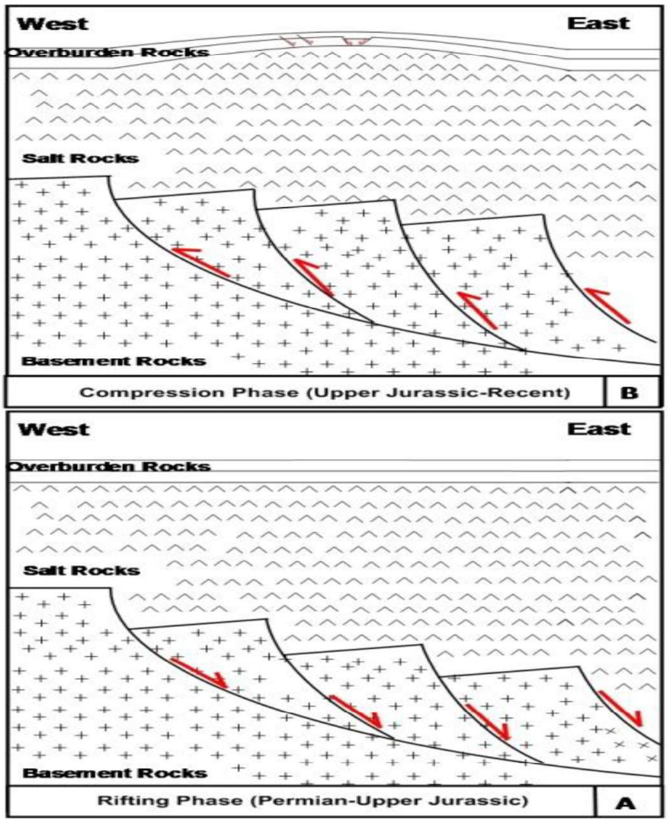


Fig.(6) The tectonic model of the Nahr Umr oil field illustrated the tectonic inversion. Panel (A) shows the rifting phase and panel (B) shows the compression phase.

5.4. Role of tectonic movements:

The interpretations of geophysical data (gravity and magnetic anomalies) have shown that the lower Mesopotamian region is controlled by recent activities. These activities are responsible for the uplift and the subsidence (Karim 1992). Kasslar (1973) divided the movement influencing Arabian Gulf and adjacent areas into three movements: (1) Pre-Pliocene Movements, (2) Plio-Pleistocene Movements – the Zagros orogeny folding, and (3) Quaternary - till recent Movements. The previous movements made the tectonic aspects of Mesopotamian Zone and its structures included Nahr Umr oil field.

6. Discussion

As the study mentioned above the geophysical interpretations confirmed the presence of salt rocks in addition to tectonic movements during the geologic history. These components worked together to many subsurface structures and one of them is the Nahr Umr field. The difference in thickness between crest and limbs of the structure where the thickness of crest is less than the thickness of limbs in all the formations of the structure referred to the effect of the vertical force may attributed to the effect of salt rocks movement below the structure. The salt may move upward due to salt mechanisms or may because of the effect of basement rocks activity which is induced the salt rocks to form the structure. The types of normal faults (parallel, radial and conjugate) are presented confirmed to the vertical force of salt beneath the Nahr Umr field.

The direction fold axis according to the structural contour maps of the Cretaceous period (Ratawi, Muddud, Sadi, Tayarat and Dammam is N NW, while it is changed obviously to NW-SE Quaternary period (Dammam structure contour map) and may attributed to the influencing by the anticlockwise rotation of Arabian Plate.

According to geophysical interpretations the fault over the crest of the Nahr Umr oil field are normal faults and they may attributed to the effect to the extensional force derived from the vertical force of salt structure growth. The dips values of limbs of the Nahr Umr oil field increase towards the latest formations, and vice versa. This may be because the latest formations are closed to the effect of salt rocks activity.

Finally, the type of faults and fold from those type are associated with salt rocks activity. This is supported the geophysical evidences, which are referred to the role of salt structure presence and role in forming the Nahr Umr field. The salt structure combined with tectonic activity and basement faults as one team to form Nahr Umr field.

7. Conclusions

1. Nahr Umr oil field is an antiform structure.
2. The dips of western limbs of all formations are bigger than the dips of eastern limbs. Also, the dips decrease towards the recent formations may due to the effect of salt structure and tectonic movement on recent formation less than latest formations. In addition, the western limb is shorter than eastern limb.
3. The fold of Nahr Umr oil field is upright, horizontal, non-plunging, asymmetric, gentle, supratenous fold and it is belong to dome structures.
4. The thickness in crest is less than thickness at limbs and this demonstrate the influence of vertical movement of salt structure and pointed out to coincidence of folding with sedimentation.
5. The curvature around the structure is variable. Where, the curvature toward the fold axis is bigger than curvature toward limbs.
6. The faults of the Nahr Umr oil field are normal faults concentrated above the top on it. These faults are radial, parallel, conjugate, and multiple offset pattern and formed a graben structure which is usually associated with salt structures.
7. The salt structures, basement fault, and tectonic movements are combined to forming the Nahr Umr field.
8. The axial fold of Nahr Umr oil field is N-S at early Cretaceous and then gradually trends toward NW-SE may attribute to counterclockwise rotation of Arabian Plate.

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42. Figure (5). Seismic section (5-BR1) shows graben in Nahr Umr field, (Total Fina Elf Co. 2001).
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