The effect of West Qurna Oil Field on the part of Euphrates river route: Geomorphic and Structural Geology integrated analysis

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Abstract

The Euphrates River Drainage Basin is located in the northern part of the Basra governorate in the south of the Mesopotamian Basin. The channel of the river is mostly straight and characterized by large loops. The channel sinuosity of this river system is analyzed in order to draw conclusions on the neotectonic activity of the region. The original status of the river thalweg was digitized from recent satellite images using the new Landsat 8 Scenes. Sinuosities at different sample section lengths were computed in a GIS software environment ArcGIS 10, providing so-called 'sinuosity spectra' for each point of the analyzed using a moving-window method and different window sizes channels. High sinuosity sections were correlated to geological subsurface structures of West-Qurna identified, indicating their neotectonic activity. A structural analysis (geometric and genetic analyses) performed to identify its type, origin and to find its relevance to main regional tectonic events. The study concluded that the river sinuosity could detect the neotectonic movements through changing the river route affected by the subsidence and uplift activity of the subsurface structure in the area.

Key Words: West-Qurna Oilfield, Structural analysis, Neotectonic Movement, River Pattern, Sinuosity Index, Window Size.

1- Introduction

The alluvial rivers are one of the landforms that changed the earth's surface through the processes of erosion and deposition. It was among significant features that used as indicators that reflect the effect of the neotectonic movement. These neotectonic movements have a direct influence on the valley floor slope. Therefore, the channel pattern, aggradation and degradation of the rivers changed answering to these movements. The aims of this paper are to: (1): analysis of river pattern for the Euphrates river near West-Qurna oil field and their relationship with the evolution of subsurface structures and neotectonic movements, (2): geological analysis (Geometric, Genetic) for the subsurface structures in this area. The West-Qurna Oilfield located about 65 km north-west of Basra city southern Iraq, between latitude (30° 53' 07"-31° 3' 16"N) and longitude (47°17'27"-47° 22' 24" E), north of Rumaila oilfiled. The oil is present in many formations, which are from bottom to top: Sa`adi, Khasib, Mishrif/Rumaila, Mauddud (Late Cretaceous), Maudud, Nahr Umr

Formations (Middle Cretaceous), Zubair, Ratawi,Yamama Formations (Early Cretaceous), Sulay, Gotnia, (Upper Jurassic) (Grabowski, 2014).

2- Geological Setting

Geographically the study area locates between the latitudes (31° 0' 47.0524"- 30° 53' 30.6918" N) and Longitudes (47° 9' 54.2129"- 47° 27' 6.9785" E). It represents by Euphrates River and part of the Hammar Marshes within Basrah Governorate. It is a flat surface where the elevation between (0-20m) above sea level (Fig. 1).

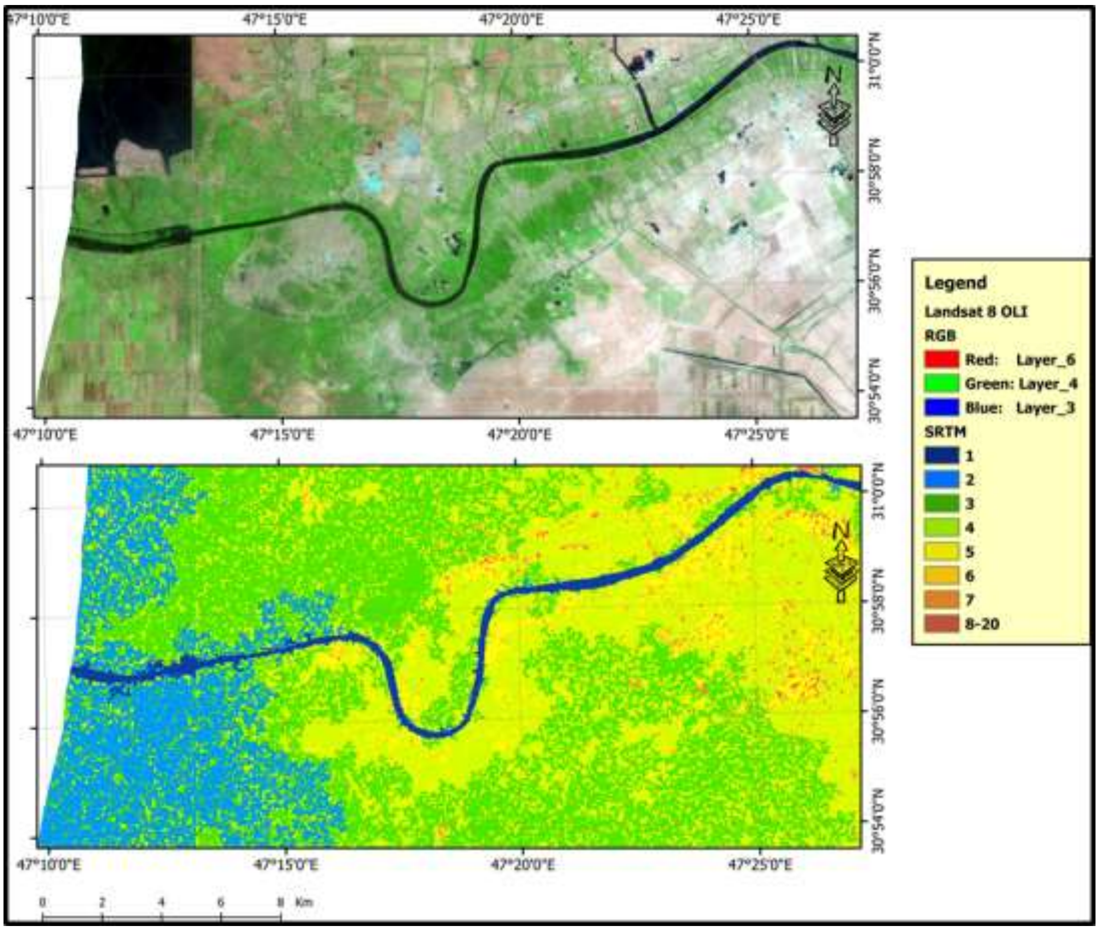

Fig. 1. Location of Study Area Location of Study Area A. Landsat 8 OLI, B. SRTM DEM

Tectonically, the area is belonging to the tectonic divisions (Mesopotamian Zone, Zubair subzone). These structures are an extension of the Unstable Shelf of the Arabian Platform (Buday and Jassim 1987; Al-Khadhimi et al. 1996). According to (Numan 1997, 2000) it lies in sagged basin within the Mesopotamian zone of the qusiplatform foreland belt of the Arabian plate. 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). This region characterized with very thick sedimentary cover and anticlinal subsurface structures separated synclinal subsurface structures. These structures associated with negative gravity anomalies that evidenced the presence of the deep-seated Infracambrian salt rocks (Karim 1989; Karim 1993; Jassim and Goff 2006; Karim, et. al, 2010). The tectonic development of Zubair subzone effected or controlled by three main tectonic sources: the Alpine Orogeny, basement faults, salt tectonics, (Al-Sakini, 1986).

Geologically, the area is characterized by thick Quaternary sediments belong to Pleistocene and Holocene Period. It is represented by floodplain sediments of lower Mesopotamian plain exemplified by the floodplain of the Euphrates and Tigris rivers, (Yacoub 1992). The sediments are grey colored and fine contain organic material and particles of Mollusca and Ostracoda varied with carbonate, clay, silt, and sand. Hammar formation underlaid these sediments was marine and lacustrine sediments, belongs to early Holocene (Yacoub 1992, 2011).

3- Method and Materials

3-1. Geomorphic Analysis (S.I.):

The geomorphic analysis by the sinuosity index performed using satellite imagery of the Landsat 8 Operational land Imager (OLI) and DEM SRTM provided form the (USGS) website with help of the GIS Environment. The Arc- Toolbox package is used for pre-image processing and post- image processing for creating suitable raster. It includes processing such (Color Composite Bands, Mosaic Different scenes, and unsupervised ISOCLASS classification). Various shapefiles (Points, Polylines, and Polygons) were created and projected into a world geodetic system (WGS 84 zone 38N), using Arc-Catalog package in ArcGIS Environment.

The different windows-sizes created in this study are (3km, 4km, and 5km) using the straight polylines that intersect with river polygon and curved polyline shapefiles (Fig.2). The length of the river polyline vertices (along channel distance) to the shorter path length straight line calculated using the attribute table for the shapefiles that make adding new fields and values and joining other tables to it for performing of sinuosity calculations processes by the list of orders (Calculate geometry, Field Calculator). Sinuosity index classified in classes based on the Schumm, 1963. It may show in ArcGIS symbology in different colors and make a sinuosity spectrum.

The sinuosity is a quantitative parameter has a several definitions by many investigators whom investigated their researches with the subject of fluvial geomorphology (Leopold and Wolman, 1957; Schumm, 1963; Langbein et. al, 1966; Mueller, 1968; Schumm and Khan, 1972). Sinuosity as a simple concept may define as the ratio of the channel length to the valley length. However, the distance on such stream can measured between two points on the stream along the channel (thalweg) divided by the straight-line distance between two points. It is called the sinuosity ratio (Schumm, 1963; Brice, 1984; Ebisemiju, 1994), that it determined whether a channel is straight or meandering (Aswathy, et al., 2008). The sinuosity index used in the formula below:

$$S.I. = \frac{the\ length\ of\ \ thalweg\ along\ the\ river}{the\ length\ of\ valley\ (distance\ of\ the\ two\ end\ points\ in\ straight\ line)}$$

Numerous studies pointed out that the planform of alluvial rivers is controlled by several factors: discharge, sediment load, and tectonic effects (Schumm, 1963; Schumm and Khan, 1972; Adams, 1980; Ouchi, 1985; Holbrook and Schumm, 1999; Schumm, et al, 2002). The tectonic movements have direct effect on the gradient or slope of the river basin. Therefore, the smallest changes in the topography affect the sinuosity of low gradient rivers (Holbrook and Schumm 1999) that make the sinuosity as an indicator to slope variance (Timár, 2003).

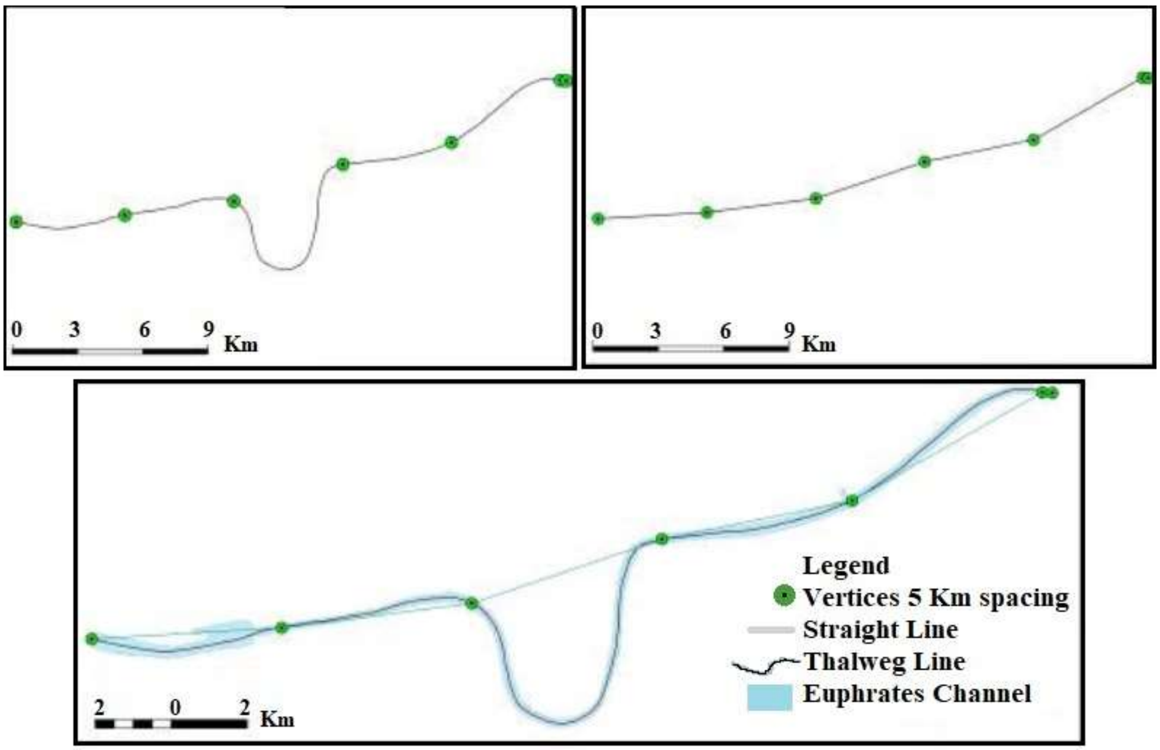

Fig. 2. Sinuosity Index computing steps

3-2. Structural Geology Analysis

A. Geometric Analysis:

An updated geological model (static model) of the West Qurna Oil Field used to construct depth and thickness contour maps via Petrel software *ver.* 2016 with scale 1:125000. All well data (locations, tops) and river reach imported in Petrel software as a readable GIS shapefiles format (Point, Polygon).

In addition, the stereographic projection utilized to analyze orientation of lines and planes and determine the structural geological attitude (interlimb angle, hinge line or fold axis, and axial surface) through Stereonet software *ver.* 9. The dip and strike [counter clockwise] calculated from the depth contour map and thickness variation from isopach contour map of Hartha, Mishrif, and Nahr Umr Formations. Fig.3

According to the essential parameters of the fold, West Qurna oil field classified 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), and (4) Fold dimensions.

1- Fold Facing: According to the direction of a closure, which is obtained from the direction of axial surface direction, the cross section and the values of dip and strike of Hartha, Mishrif, and Nahr Umr Formations are an anticline structure (Table 1).

2- Fold Orientation: it includes two parameters:

Dip of axial surface: An axial surface defined as a surface that connects fold hinge lines (Groshong, 2006). Stereographic projection determined the attitude of the axial surface of Hartha, Mishrif, and Nahr Umr Formations as shown in (Tabel.1), therefore West Qurna Oil field structure classified as upright fold.

Plunge of the hinge line (fold axis): Hinge line is a line included the maximum curvature on the surface of a layer (Groshong, 2006). However, it represented as straight line called Fold axis (Fossen, 2010). Hartha, Mishrif, and Nahr Umr Formations classified as a horizontal fold or non-plunged fold because the degree of the hinge line plunge is less than 10º (Table 1).

Symmetry of the fold: West Qurna Oil Field considers as an asymmetrical structure because the dips of left limbs are more than right limb for Hartha, Mishrif, and Nahr Umr Formations are (Table 1).

Table 1 Stereographic Projection results

Formation	Left Limb	Right Limb	Interlimb Angle	Hinge Line	Plunge of Hinge line
Hartha	5º/258º	1.5º/78º	173.5º	88.2º/348º	1
Mishrif	2.4º/268º	1.6º/88º	176º	89.6º/358º	1.3
Nahr Umr	5º/266º	3.8º/86º	171.2 º	89.4º/356º	1.9

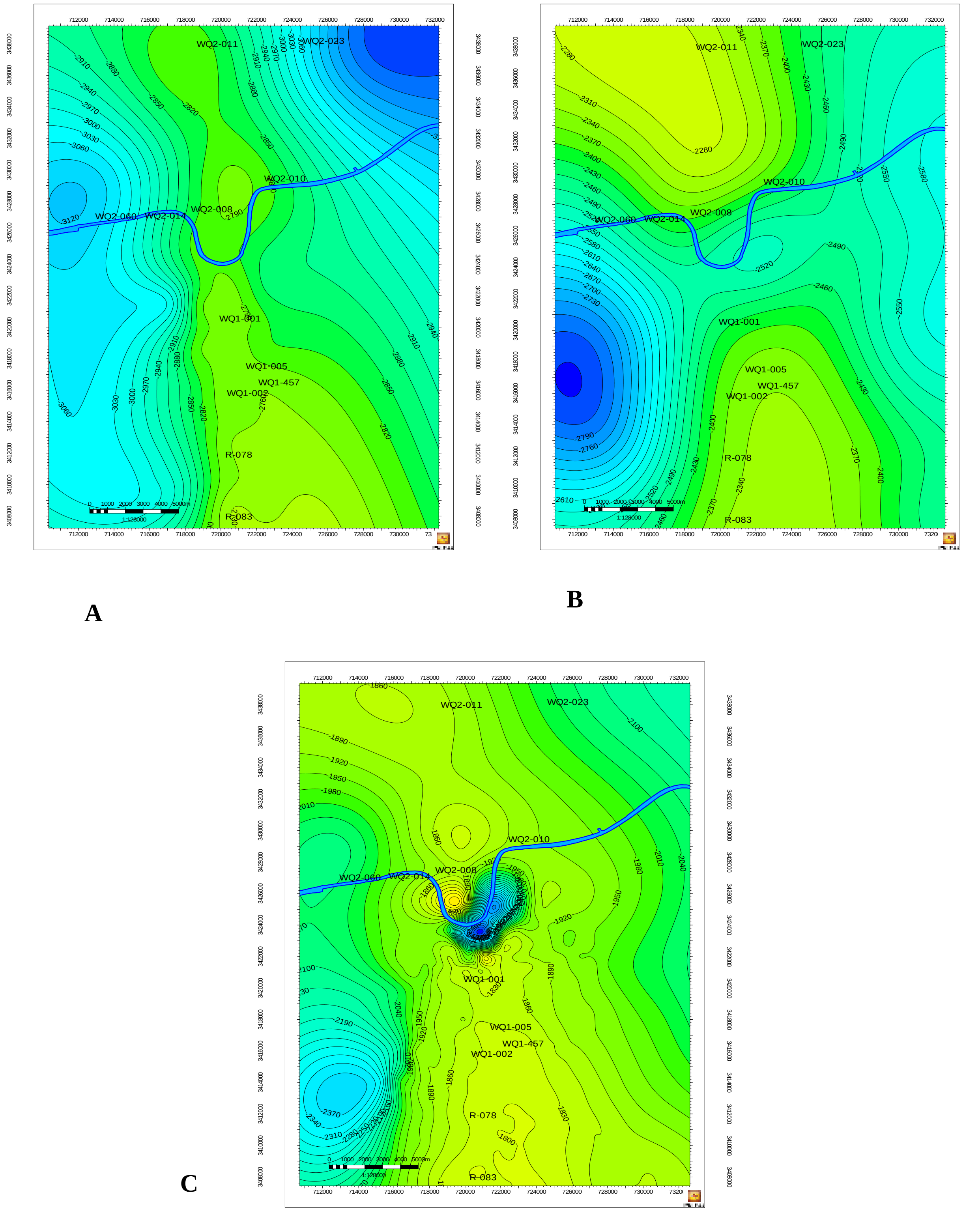

Fig. 3. Structural Subsurface Map of the three top culminations of West-Qurna Oil Field A, B, C Nuhr Umr, Mishrif, and Hartha respectively.

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 uses two parameters: the interlimb angle and variation in thickness.

Interlimb Angle: The angle between the limbs of a fold is called the interlimb angle (Fleuty, 1964). The interlimb angle of Hartha, Mishrif, and Nahr Umr Formation are 173.5º 176º and 171.2º, respectively, therefore West Qurna oil field classified as gentle fold.

The variation in thickness: The crest's thickness of Hartha, Mishrif, and Nahr Umr Formations are less than its limb thickness. This type of fold called supratenous fold and this type of fold formed when the sedimentation coincides with folding.

B. Genetic Analysis:

Three combined main forces worked together to produce subsurface anticline structures in southern Iraq included West Qurna Oil field, these are tectonic Movements, reactivated basement faults, and Hormuz salt structures (Karim 1989, 1993; Al-Sakini 1993; Numan 1997; Jassim and Goff 2006) shown in tectonic model (Fig. 3) (Lazim, 2011). Geophysical surveys of southern Iraq indicated that the association of negative gravity could be because of deep-seated salt beds of Infra-Cambrian salt beds, while, the positive gravity referred to basement uplift (Karim 1989, 1993; Jassim and Goff 2006;Karim et. al, 2010). Karim et. al. (2010) referred to negative anomaly associated with north West Qurna oil field, this may relate to Infra-Cambrian salt structures (Hormuz salt structure).

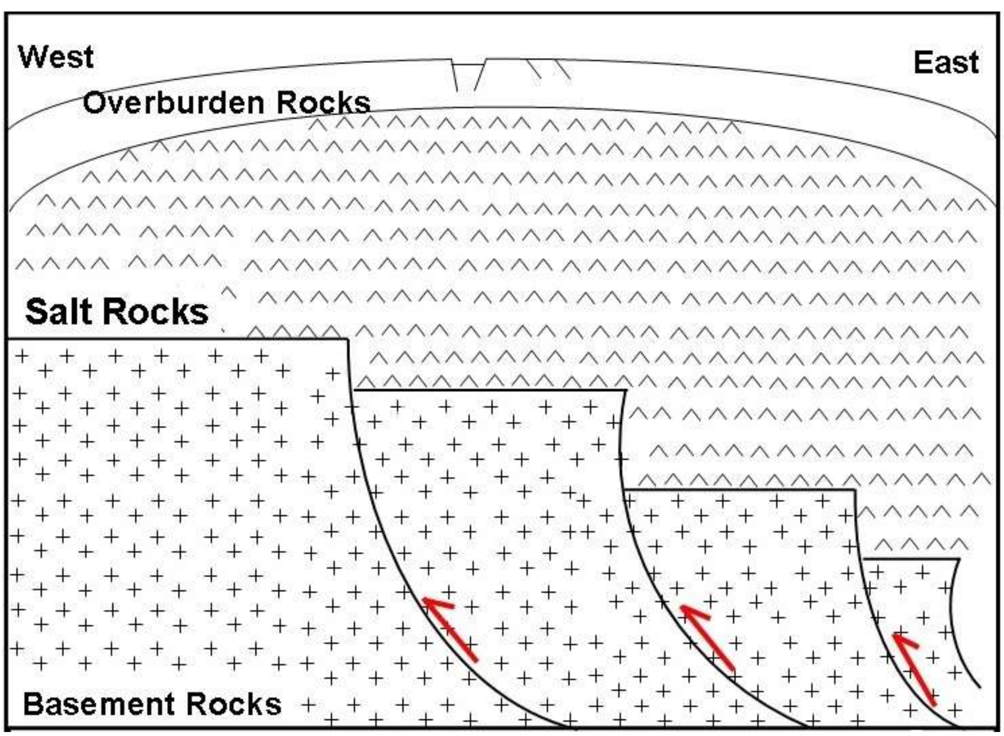

Fig. 4 Tectonic model for oil fields in southern of Iraq at compression phase (Upper Jurassic till recent) (Lazim, 2011).

4- Results and Discussions

4-1. Geomorphic Analysis (S.I.)

Sinuosity indices were computed according to the definition of Schumm (1963). Then it has been classed into classes agreeing to the classification of Schumm (1986) table (2). The studied segments of the Euphrates River starts from the border of Basra Governorate Mudaina city, and ends to the confluence of Tigris and Euphrates rivers at Qurna with length about 32 Km, and the sinuosity spectrum was showed for each section.(Fig. 5)

Table 2. Sinuosity values of Euphrates river course 4 Km window size.

Segment No.	Sinuosity Value	Sinuosity Class	River Morphology	Frequency	Percentage%
1	1.02	1-1.05	Straight	5	62.5
2	1.01	1.06-1.3	Low sinuous	2	25
3	1.24	1.31 -3	Meandering	1	12.5
4	1.42				
5	1.13				
6	1.02				
7	1.03				
8	1				Sum=100%

The sinuosity index computed using different window size (3, 4, 5) Km. However, the sinuosity indices are scale sensitive (Zámolyi et al., 2010) but it is a valuable when it exhibit same morphological changes at a several window-sizes (Petrovszki and Timár 2010). It generally depend on the planform of the river (Meander) where it compound bends or single bends for large or small window size respectively, According to Gasparini, 2016 (pers.comm, 05 June, 2016). The morphological feature of Euphrates River is single bend, so the small window size is suitable for the Euphrates river reach in this study. This is compatible with the results of the structural analysis, where it displayed the saddle in the West-Qurna Field Fig.3.

Euphrates River, which runs northwestern of Basra city, exhibits markedly straight pattern where all studied segments have sinuosity index equal to (1) table (2) at different window sizes.

At Distance approximately (8-10km) from the Euphrates River appears sudden change in sinuosity and in river morphology from straight to the sinuous pattern in window size 3, 4 Km, and straight to the meandering pattern in window size 5 km. This region is the location of the West-Qurna Oil filed. More studies pointed out that the Euphrates River influenced by West-Qurna subsurface structure (Al-Sakini, 1993; Jassim and Goff, 2006).

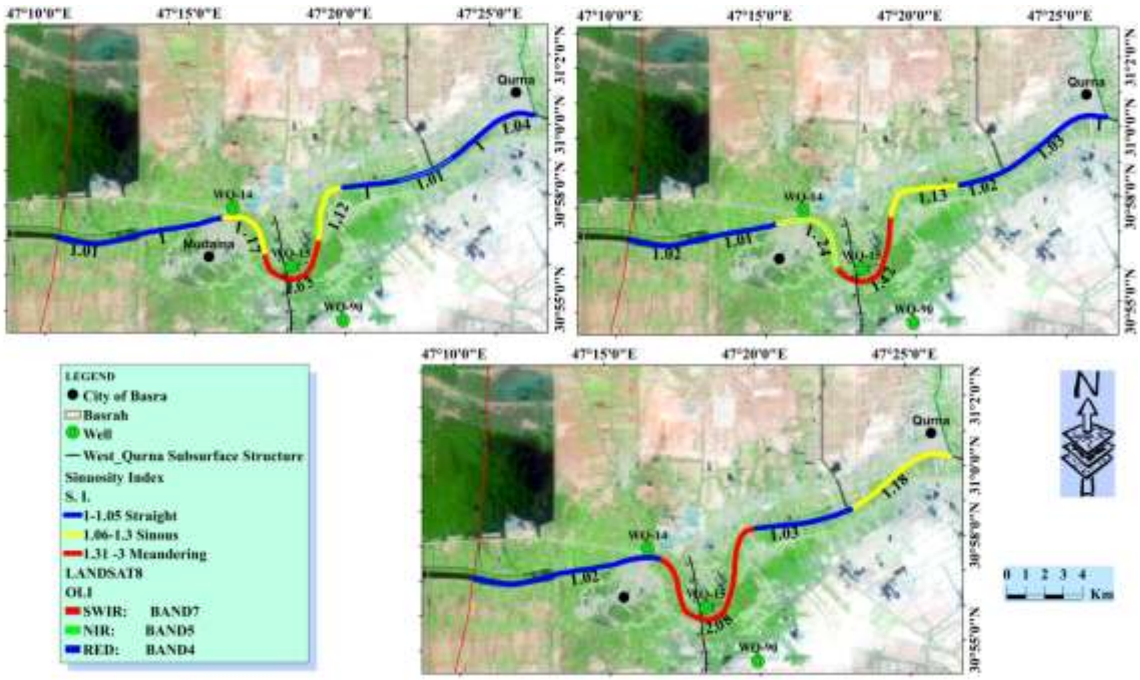

Fig. 5 Sinuosity index for Euphrates River with different window size 3, 4, 5 kilometers.

In the next segment, the Euphrates River exhibits new sudden change in sinuosity and river morphology from sinuous to meandering pattern especially in window size 3, 4 Km. These changes in sinuosity values are corresponding with West-Qurna subsurface structure. It exhibits increasing in its value downstream of the uplift axis and decreased upstream of uplift axis (Ouchi, 1985). This result is verified clearly in the window size 3 or 4 km (Fig, 4), where the sinuosity value approached between (1.6-1.4) respectively, whereas the two sides approximately between (1.06-1.3) which it was showed sinuous planform. The subsurface structural map in this area revealed a subsidence represented by a saddle in West-Qurna Field (Fig.). The next segments of Euphrates River continued in straight pattern toward its crosses with Tigris River near Qurna city Fig. 5.

4-2. Structural Geology Analysis Results:

The results of geometric analysis for the physical elements of West Qurna field (Fold facing, Fold orientation, Fold shape in profile plane, Fold dimensions) used in genetic analysis to understand the structural picture for the field. The current study proposes a scenario for West Qurna oil field, which is at Cretaceous period the tectonic activity is prevailed with the result of abduction between Arabian and Iranian plateaus, which led to reactivate the basement faults, and induced salt structure below the study area and made uplift then arching, and thinning features.

5- Conclusions

1. Euphrates River displayed three type of planform channel (Straight, Sinous, and Meandering). These three types emphasized the neotectonic movements on the Mesopotamian basin in general and studied area.
2. The multiple window size of sinuosity is more valuable tool for detection the tectonic effects on the rivers, especially when it detect same morphological change in all window size.
3. GIS techniques are a good tool for representation a sinuosity as sinuosity spectra.
4. Sinuosity of the river has a good connection with the position of subsidence and uplift of the subsurface morphostructure elements through changing pattern.
5. West Qurna oil field is an anticline, upright, non-plunge, asymmetrical, gentle fold.
6. The thickness variation of West Qurna oil Field, when the crest is thinner than its limbs may attribute to bending force due to salt structure force.
7. Three combined main forces create West Qurna oil field. These are tectonic movements, reactivated basement faults, and Hormuz salt.
8. The general fold axis direction of West Qurna oil field is N-S with little inclination toward NW-SE with (2° to 4°) for Hartha, Mishrif, and Nahr Umr Formations, respectively. This inclination may relate to counterclockwise rotation of the Arabian plate and this direction compatible with surrounding fold axes fields of southern Iraq.
9. There is no saddle between West Qurna and North Rumaila field, but there is a shallow saddle inside West Qurna culmination associated with change in Euphrates River and may it the reason of the change in the river route, or the change of river sinuosity.

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