

**MINISTRY OF HIGHER EDUCATION  
AND SCIENTIFIC RESEARCH  
UNIVERSITY OF DIYALA  
COLLEGE OF SCIENCE  
DEPARTMENT OF PETROLEUM  
GEOLOGY AND MINERALS**



**Petrophysical Evaluation and Seismic Interpretation  
of Nahr-Umr Formation in East Baghdad Oil  
Field/Central Iraq**

A thesis submitted to the Council of the College of Science- University  
of Diyala in partial fulfillment of the degree of master in Geology/ Earth  
Science

**By  
Farouq Ali Hussein  
B.Sc. 2022  
Supervised by  
Prof. Dr. Munther Dhahir Nsaif**

## **Abstract**

Petrophysical evaluation of Nahr Umr Formation in the East Baghdad oil field was carried out using well log data from two wells (EB-4 and EB-6). The logs were corrected for environmental effects before analysis. The study focused on determining the rock type, shale volume, porosity, and water saturation. Rock type was determined by neutron-density crossplots, and porosity was estimated from density, neutron, and sonic logs. Archie's equation was used to assess water saturation.

The formation is divided into two main parts: an upper part mainly consists of sandstone with thin shale layers, and a lower part mostly consists of shale. The evaluation focused on the upper part, which showed good porosity values ranging between 0.10 and 0.20, indicating possible reservoir properties. However, water saturation was high, ranging from 70% to 80%, which suggested poor reservoir quality. The lower part contained more clay and water, which reduced its petrophysical quality and made it unsuitable as an oil reservoir.

In the seismic aspect, a 3D seismic survey was conducted in the South-2 area of the East Baghdad Field, covering approximately 383.1 km<sup>2</sup>, aiming to update the structural interpretation of the Nahr Umr Formation. The study utilized high-resolution 3D seismic data, which provided detailed structural information to enhance the understanding of the formation's subsurface structure. A synthetic seismogram for well EB-15 was generated using the GeoFrame software, where the picked reflector of the Nahr Umr Formation appeared as a trough on the synthetic trace. Seismic interpretation of the Two Way Time, velocity, and depth maps revealed normal faults trending northwest-southeast (NW–SE), which are truncated in the northwestern part and reappear after a horizontal displacement, indicating the presence of a strike-slip fault (E–W). Additionally, transverse faults trending E–W and NE–SW were identified, contributing to the formation of

multiple structural closures. The southern part of the field is characterized by an anticlinal structure intersected by normal, strike-slip, and transverse faults, reflecting the geological complexity of the area and offering favorable conditions for hydrocarbon accumulation.

Variance attribute sections of the Nahr Umr Formation revealed that the area is affected by listric growth normal faults with dendritic branches trending NW–SE, consistent with the East Baghdad Field trend. Transverse faults trending E–W and NE–SW were also identified. The intensity of these faults increases with depth and is most prominent within the Nahr Umr Formation, providing additional insight into the structural complexity and helping delineate fault system types.

# **Chapter one**

## **Introduction**

## **1-1 Preface**

The East Baghdad Oil Field was discovered in Baghdad Governorate in 1974 by the Iraq National Oil Company. The field is divided into six main structures parallel to the northwest-southeast axis: Northern Extensions, Taji, Rashidiya, Omaran, South 2, and South 1. This research describes part of the South 2 region on the eastern edge of the Mesopotamian Basin.

Petrophysics plays a vital role in illustrating the underground geologic formations by studying the physical characteristics of rocks from well logs. This work focuses on the characterization of porosity, permeability, and fluid saturation, which are critical parameters in the evaluation of the abilities of rocks to store and conduct hydrocarbons. The comparison between seismic and well data enables geologists to increase the confidence with which they interpret the geological environment and to better resolve properties in the Formation (Asquith and Krygowski, 2004).

For interpreting seismic data, various subsurface structures are shown in the seismic section and time and velocity maps to recognize structural traps. 3D seismic can provide detailed information of the established nature of the rocks into the Earth, which is useful for better estimations of the location and the size of the hydrocarbon reservoirs as well as the planning for the development of these fields (Yilmaz, 2001). Seismic Data and seismic maps were checked against existing well data to help interpret results and increase confidence.

This work is significant since it concentrates on the Formation of Nahr Umr at the East Baghdad Field, which is one of the major formations in the region. It uses the petrophysical interpretation with seismic interpretation to determine the type of rock properties and structural setting of this unit. The present results contribute to a better geological interpretation of the subsurface extensions. Field measurements and published technical papers were employed in support of the analysis to guarantee its accuracy.

## **1-2 Location of Study Area**

The research area is situated in the southern section of the East Baghdad Oil Field, south of the Diyala River, eastern side of the Mesopotamian Basin, and it falls within Diyala and Baghdad Governorates (Figure 1-1). The area extends over 383.1 km<sup>2</sup> and has been chosen to refine the structural analysis of the Nahr Umr Formation (O.E.C., 2013).

This location was chosen due to the availability of 3D seismic survey data acquired in 2009, along with well log data for EB-4 and EB-6. These data provide a reliable basis for evaluating the petrophysical properties and structural setting of the Nahr Umr Formation in the East Baghdad Oil Field.

The surface coordinates were defined using WGS84 system, as shown in Table (1-1).

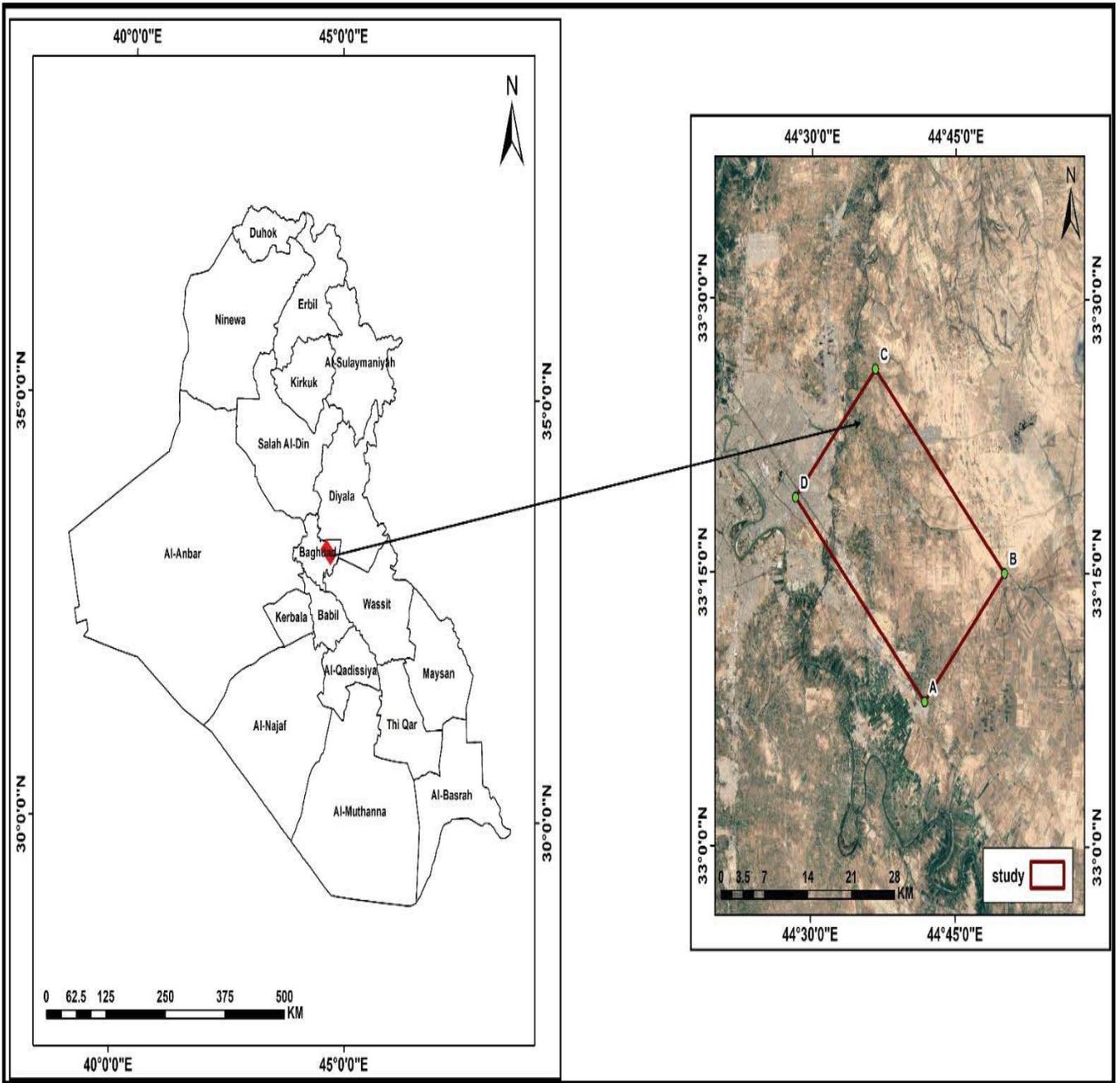


Figure 1-1: The location of the study area.

**Table (1-1):** The coordinates of the study area (O.E.C., 2013)

Station	Latitude	Longitude
A	33°7'56.88"N	44°41'47.32"E
B	33°14'59.26"N	44°50'4.46"E
C	33°19'6.09"N	44°28'19.95"E
D	33°26'9.34"N	44°36'37.05"E

### **1-3 Tectonic Setting**

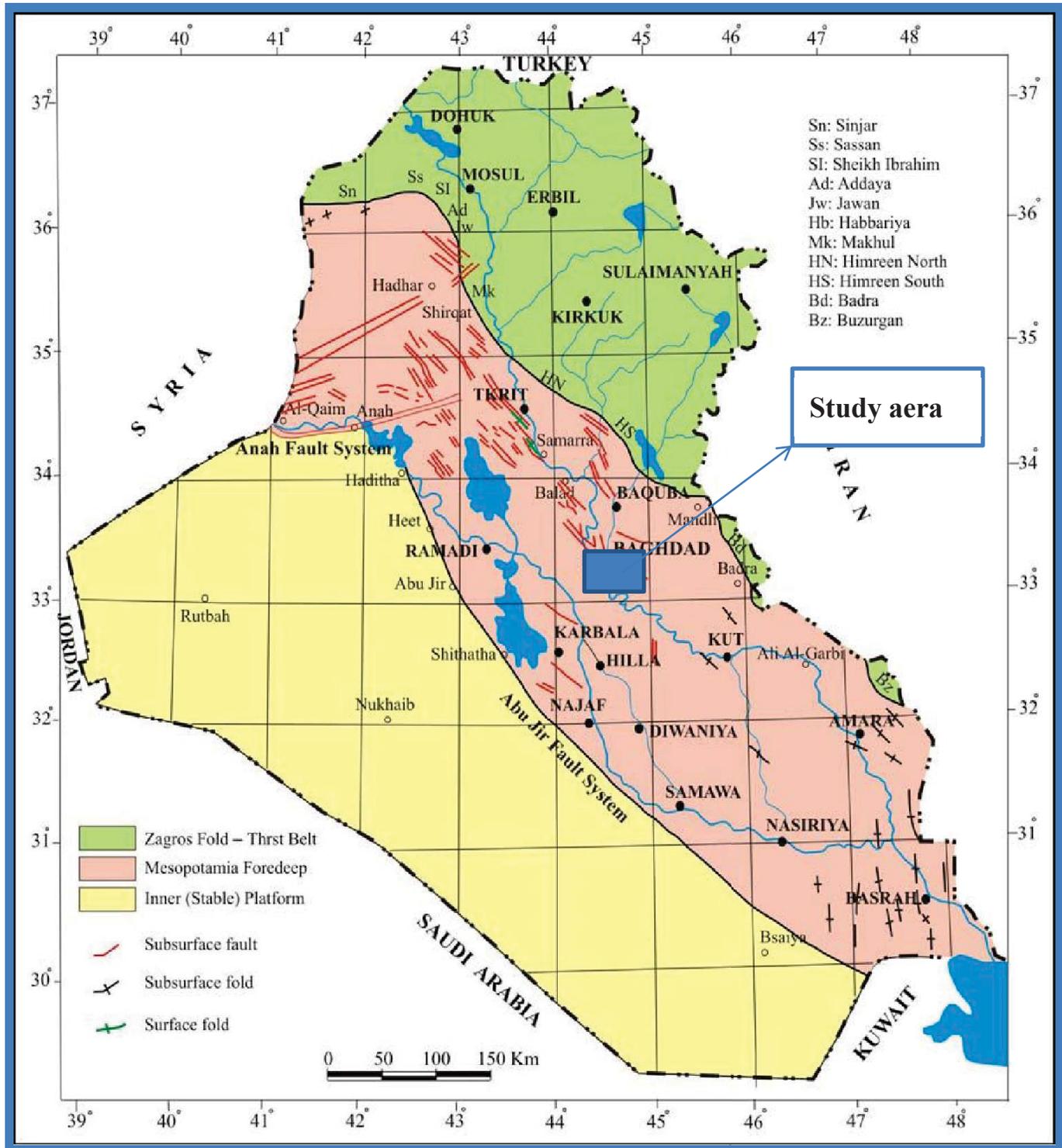
The East Baghdad Field is characterized by a complex structural setting influenced by several fault systems, most notably faults trending in a northwest-southeast direction (Figure 1-2), associated with the regional tectonic framework (Sharland et al., 2001).

The field lies within a large asymmetrical anticline, where the northeastern flank dips more gently compared to the steeper southwestern flank (Hamed, 1998).

Structural studies indicate that the origin of this configuration is related to the development of oblique-slip growth faults, followed by subsequent folding and faulting due to continued tectonic activity (Khawwka, 1989).

East Baghdad oil field influenced by both extensional and compressional forces, which contributed to the formation of structural folds within the deep Mesopotamian Trough. These tectonic influences resulted in major and minor structural trends that generally follow a northeast-southwest orientation. Such forces led to the development of two primary fault systems, along with the

emergence of domal structures in the form of small domes, half-domes, or folded features (O.E.C., 2012).



Figure(1-2) Tectonic map of Iraq (Modified after Fouad, 2010)

## **1-4 Stratigraphic Column**

The geological column of the study area, as illustrated in Figure (1-3), represents the vertical lithological section of the East Baghdad EB-1 well, which was the first drilled in the field. This well penetrates the largest number of geological formations in the region.

Below is a description of the Formation of Nahr Umr:

### **-Nahr Umr Formation**

In the eastern region of Baghdad, the Nahr Umr Formation consists of soft, fine-grained calcareous sandstone with frequent pyrite content. It sometimes includes clay or sandy limestone layers as well. There are also shale beds. At the base, the Formation unconformably overlies the older Shuaiba Formation, reflecting a transition from carbonate to siliciclastic rocks (Jassim & Goff, 2006).

This unconformity distinguishes the Nahr Umr Formation from the underlying Shuaiba Formation, where the Shuaiba Formation was deposited in a carbonate environment, while the Nahr Umr Formation was deposited in a siliciclastic environment. This transformation occurred during the early Cretaceous periods as a result of sea level fluctuations and tectonic activity (Al-Sayyab et al., 1982).

The Nahr Umr Formation was deposited in a mixed terrestrial, shallow-marine, tidal, and deltaic environment and open marine Environment (Al-Sayyab & Valek, 1968).

The upper bound of the Nahr Umr Formation mostly matches up with the Maudud Formation above it, and the contact is gradual (Jassim & Goff, 2006).

In southern Iraq, the Albian stage (Lower Cretaceous) contains the prominent Nahr Umr Formation. It is primarily composed of sandstone interspersed with shale and occasionally siltstone. The sandstone is highly porous and permeable, and it represents one of the main oil reservoirs in such as Basra and Zubair fields. Cross-bedding and ripple marks indicate that the sandstone originated in high-energy conditions, including river, delta, and shallow sea (Aqrawi et al, 2010).

The thickness of the Nahr Umr Formation gradually decreases toward the East Baghdad Field from southern Iraq, ranging between (88 - 101.5) meters. This decrease is attributed to the location of East Baghdad near the basin margin, where reduced sediment supply and finer grain deposition are observed compared to the southern regions (Jassim & Goff, 2006).

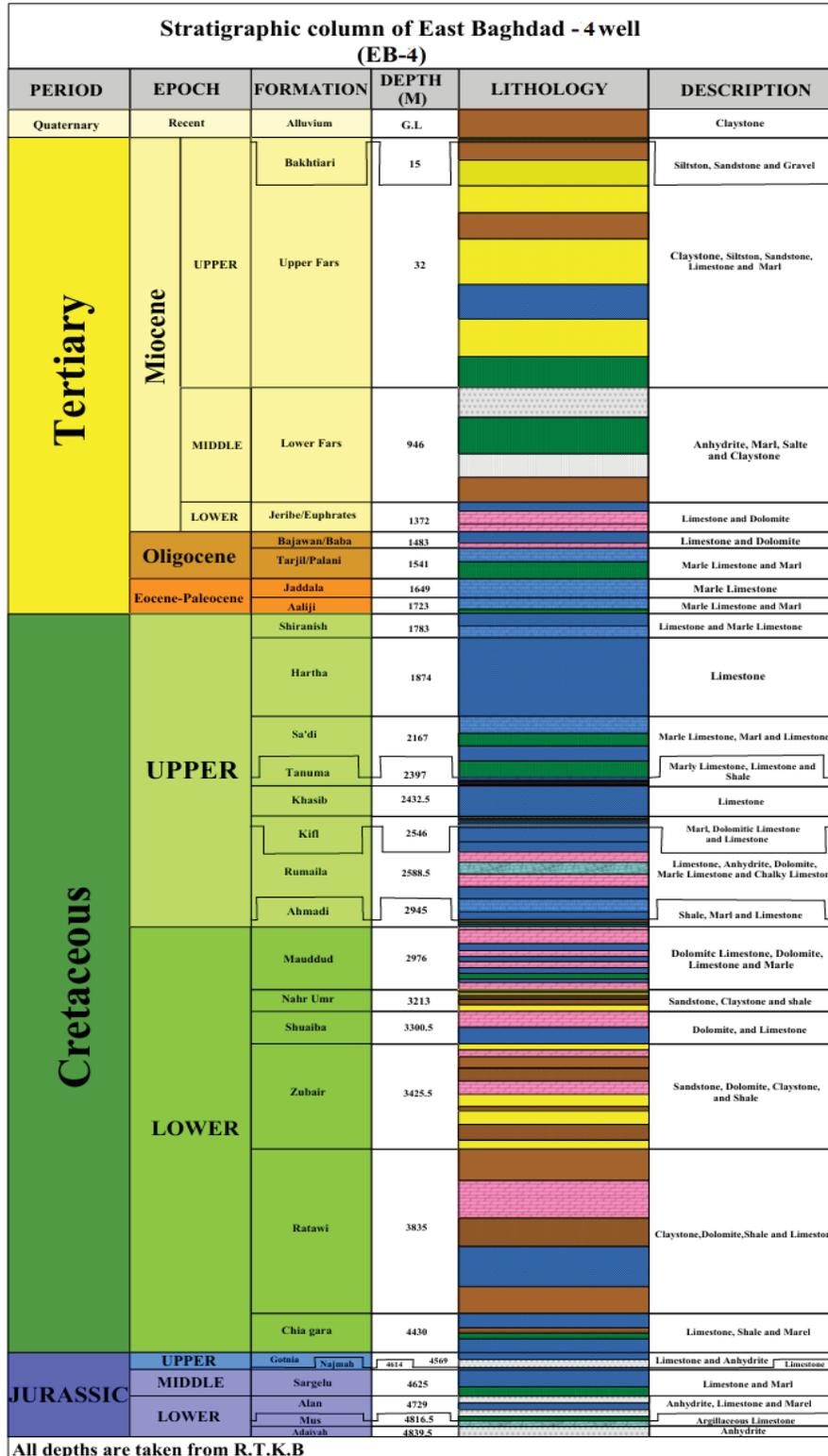


Figure (1-3) Geological section of EB-4 well , all depths are taken from R.T.K.B (O.E.C., 1979)from (Al-Banna & Al-Khafaji,. (2021))

## **1-5 Previous Geophysical Surveys in East Baghdad Oil Field**

### **1-5-1 Gravity Surveys**

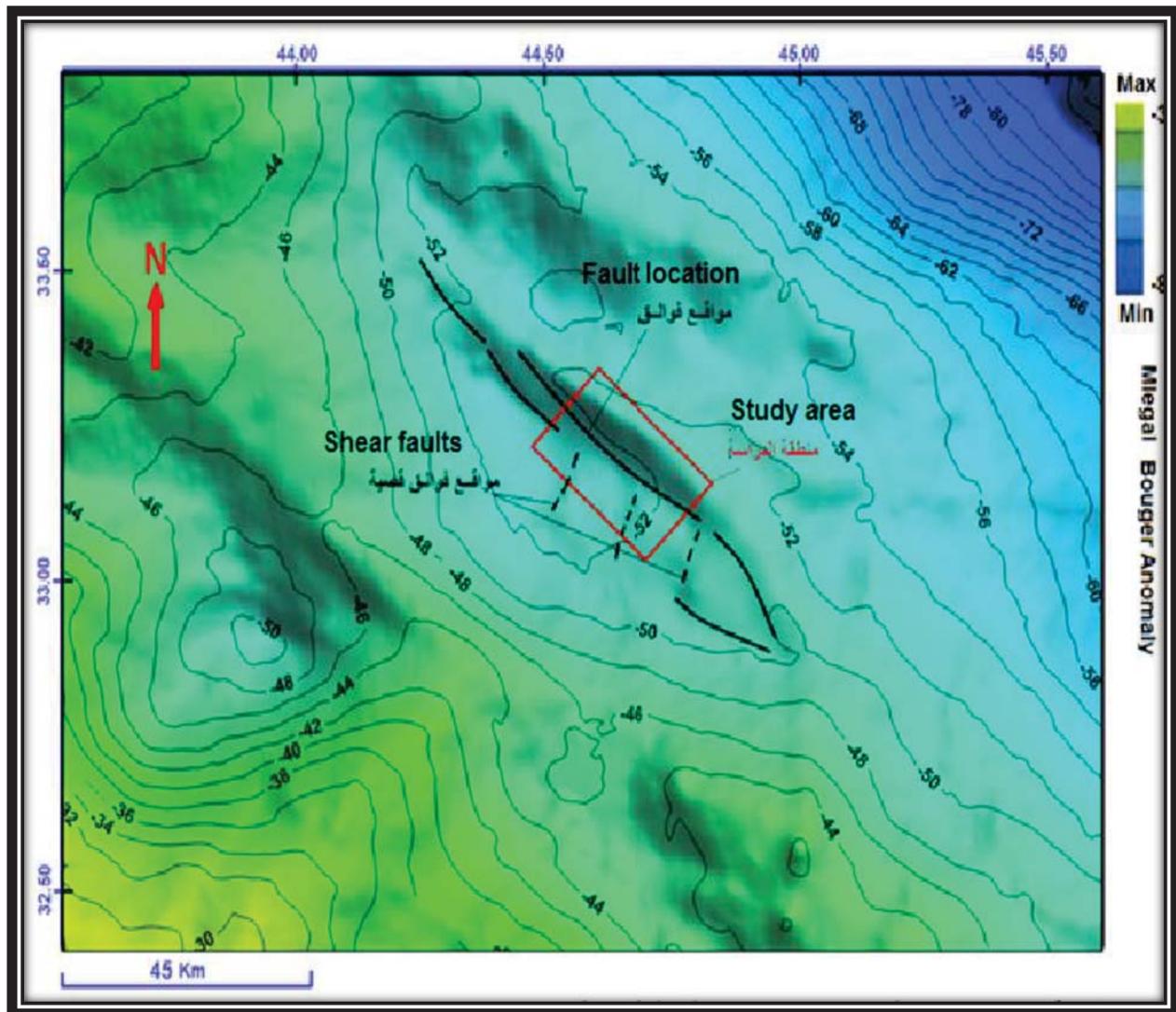
The study area was covered by gravity surveys conducted by the Iraq Petroleum Company (IPC) during the 1940s. In 2010, the British company Getech reprocessed and corrected this data to extract updated information.

The surveys indicate that areas where basement rocks are exposed or close to the surface show high gravity values, while gravity decreases with depth. In other words, gravity reflects the overall shape of the sedimentary cover. Areas with relatively high gravity suggest structural uplift, while areas with relatively low gravity indicate a structural depression or sedimentary basin.

It is important to note that high gravity may also indicate the presence of relatively high-density rocks, while lower values may reflect the deposition of lower-density rocks compared to the surrounding formations. These interpretations are further confirmed by comparing gravity data with magnetic maps and with rock density information from deep well logs.

The Bouguer anomaly map corrected for the study area shows relatively uniform gravity values (approximately -52 mGal), with broadly spaced contour lines. The map indicates a structural uplift in the northeastern part of the area and a depression in the southwestern part. It also shows that the East Baghdad area is located on the flank of the basin, with gravity values decreasing eastward toward the main sedimentary basin of Iraq.

Overall, the data suggests that the sedimentary column in the area has moderately uniform rock densities, based on the gravity distribution shown in the map (Figure 1-4).



Figure(1-4) Bouguer anomaly map of East Baghdad oil field and surroundings area(Saed *et al.*, 2012)

### 1-5-2 Magnetic Surveys

The study area was covered by airborne magnetic surveys conducted at approximately 140 meters above the topographic surface. These surveys were originally carried out by the French company C.G.G. in 1974. Later, in 2010, the British company Getech corrected and processed the data to extract the magnetic information.

The fundamental assumption is that basement and volcanic rocks exhibit higher magnetic susceptibility compared to sedimentary rocks, which generally have lower magnetism. Consequently, magnetic sensitivity increases over structural features or areas where basement rocks are relatively closer to the surface, while it decreases in concave zones or sedimentary basins.

Magnetic derivative maps were used to interpret the geological structures, including:

1. Total Magnetic Intensity (TMI) Map:

This map reflects the shape of the Earth's crust, where magnetic intensity values range between 4900 and 4950 nanoteslas. The map displays long-wavelength anomalies indicating areas of deep sediment accumulation and basement depth, with a clear structural convexity observed in the northwestern part of the study area and a concavity located outside the southwestern boundary (Figure 1-5) (Saed et.al.,2012).

2. Reduced To Pole (RTP) Map:

This map is generated by correcting the inclination of the Earth's magnetic field to better position magnetic anomalies over their true geological sources. The correction was applied along the longitude range of  $44^{\circ}$  to  $45^{\circ}$ , passing through the study area. The RTP map shows a moderate magnetic intensity distribution ranging from 4900 to 4940 nanoteslas. It highlights a structural closure with convex geometry in the northwest, and a concave axis extending from the southwest toward the northeast, corresponding to the sedimentary basin. A gradual decrease in magnetic intensity is observed along this trend (Figure 1-6) (Saed et.al.,2012).

These results indicate that basement rocks in the study area are deeper compared to neighboring regions, confirming the presence of structural features characterized by both convexity and concavity within the studied area.

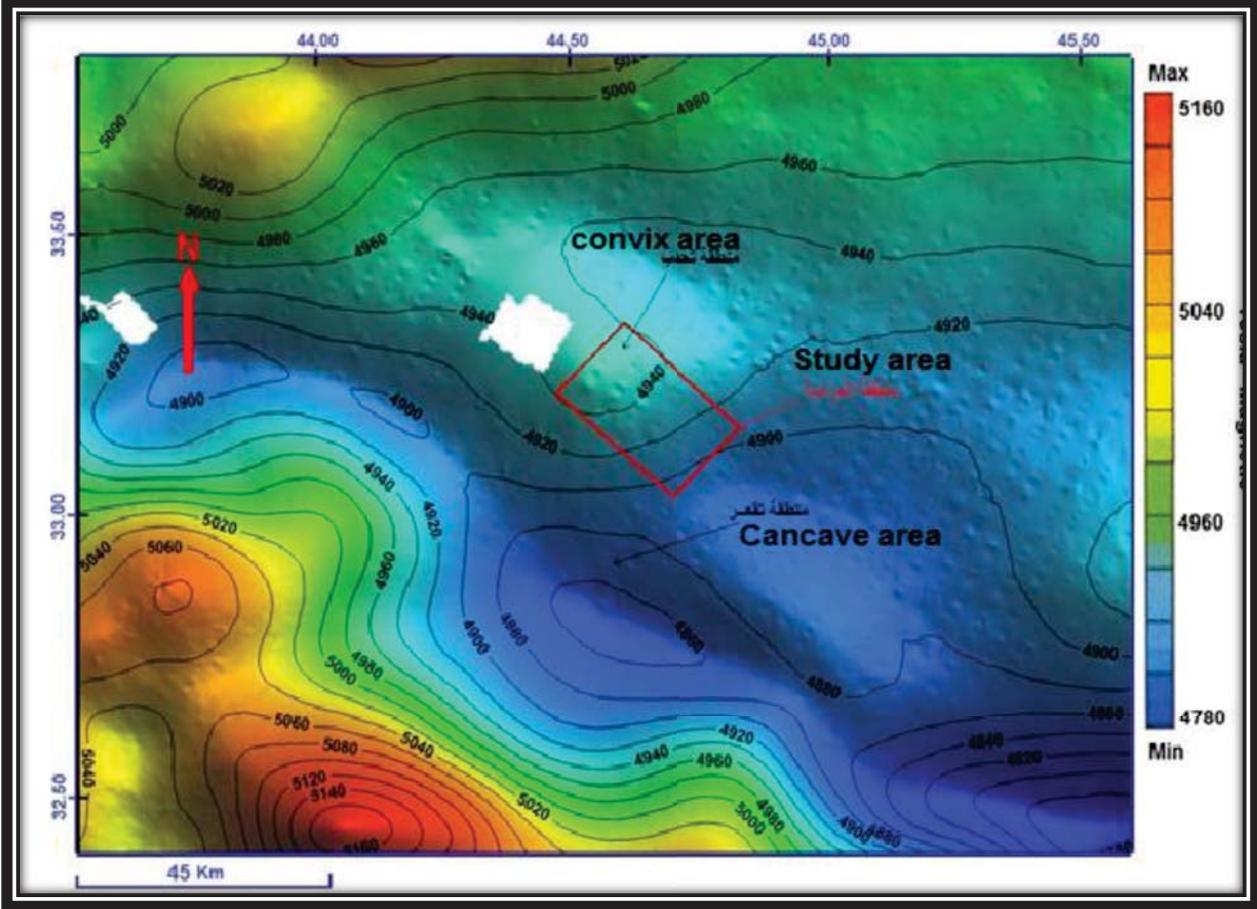


Figure (1-5): Total Magnetic Intensity TMI map of central Iraq including study area (Saed et.al., 2012).

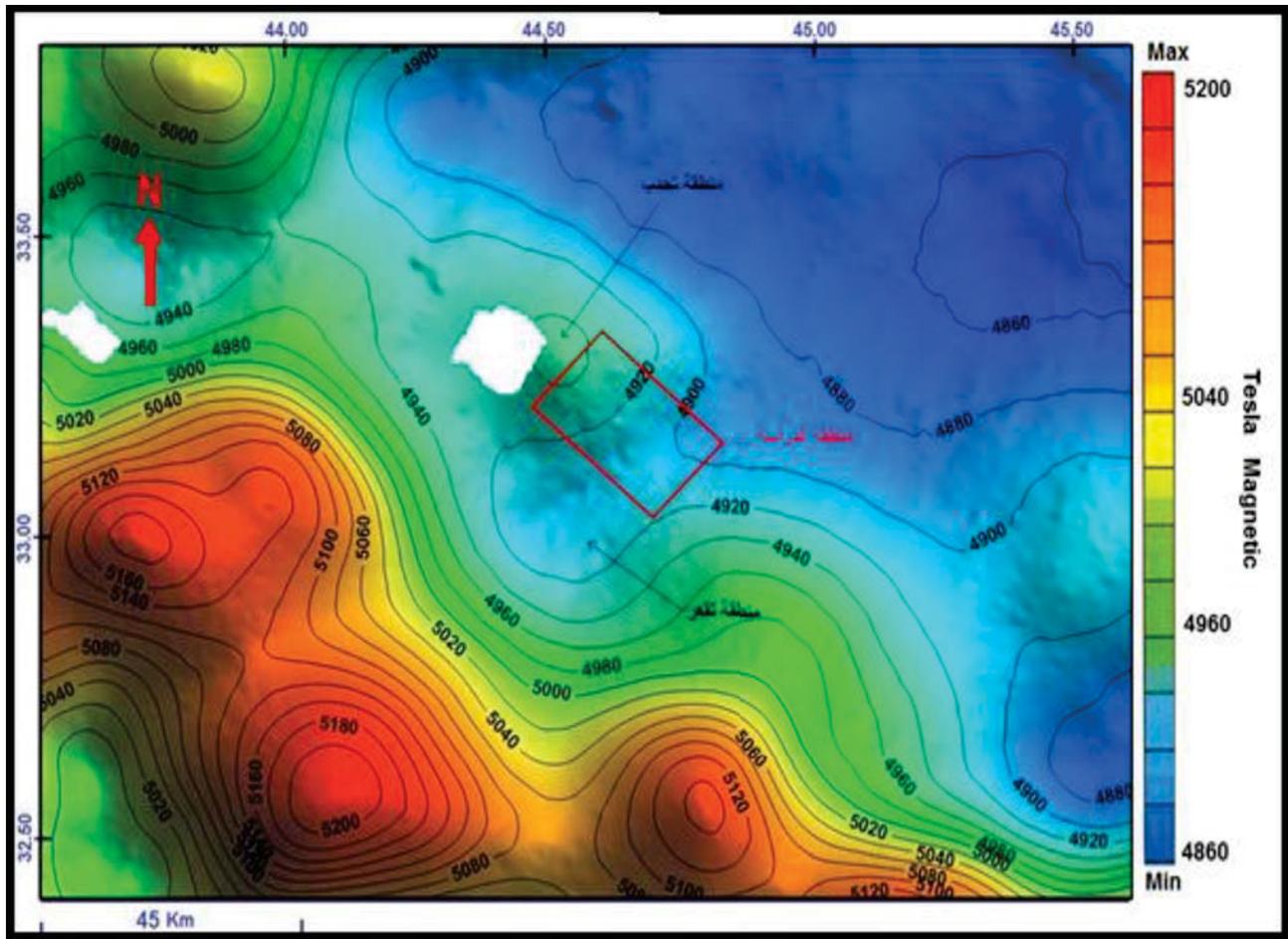


Figure (1-6): Reduced To Pole (RTP) map of central Iraq including the study area (Saed et.al., 2012).

### 1-5-3 Seismic Surveys

- Many previous seismic surveys have been carried out by Ray Company (Iraqi seismic party no.3) between 1959-1960 with a single coverage. The Rom petrol company surveyed the area in 1974 for the Iraqi national oil company, with coverage of 600% in 1978. Another seismic survey was accomplished by the same company with coverage of 2400%, and in 1981, another seismic survey was accomplished with the same coverage. The results of previous surveys are not homogeneous, which leads to reviewing

these surveys and depending on detailed surveys to illustrate the structural picture, especially in the area that is considered as faulted area.

- Two dimensional exploratory survey was carried out in 1974-1975 by the Romanian seismic party (Rom Petroleum) central spread, coverage 6%, single drilling, and dynamite energy.
- Two dimensional detailed survey carried out in 1978 by the Romanian seismic party (Rom Petroleum) covered 24%, single drilling, dynamite energy, and central single spread.
- In 2009, a detailed study of two dimensional seismic survey, carried out by Iraq seismic party No.2.
- In 2010, a detailed study of three dimensional seismic survey, carried out by Iraq seismic party No.2.

## **1-6 Pervious Petrophysical and Seismic Studies**

### **1-6-1 Previous Petrophysical Studies in East Baghdad Oil Field**

- Hameed et al. (2018) characterized the petrophysical properties of the productive formations in East Baghdad through well log interpretation for a number of wells. The study was conducted using cross-plot analysis to differentiate lithologies and fluid types, for the detection of primarily reservoir potential zones.
- Ali and Mahdi (2019) made an integrated petrophysical study of Hartha and Saadi formations in the East Baghdad Field. Effective porosity and hydrocarbon saturation were calculated using the gamma-ray, resistivity, and neutron-density logs, which facilitated understanding reservoir production.
- Mansour et al. (2020) analyzed the petrophysical and geomechanical properties of the Lower Cretaceous interval in the East Baghdad Field. The

goal of the research was to evaluate the distribution of rock strength and porosity, allowing well log interpretation and core integration to add value to drilling and completion decisions.

- Khalil et al. (2021) conducted a petrophysical evaluation of the Zubair Formation in the east Baghdad field based on logs of some wells. This analysis comprised porosity, permeability, and water saturation, which served to characterize reservoir quality and areas of potential productivity.
- Al-Banna, A. S., & Al-Khafaji, M. A. (2021) applied the RPTs on the EB-4 well logs in East Baghdad Field to estimate petrophysical properties of Nahr Umr, Shuaiba, and Zubair formations. After applying the two inversions, the Nahr Umr Formation was found to consist largely of sandstone and shale, and showed possible hydrocarbon zones based on acoustic impedance and  $V_p/V_s$  ratios.

### **1-6-2 Previous Seismic Studies in East Baghdad Oil Field**

- JAPEX Company (Japan Petroleum Exploration) 2006, studied the East Baghdad Field, Central Iraq, to develop reservoirs in the Zubair Formation and Hartha Formation.
- In 2012, Oil Exploration Company, geophysical and geological department, evaluated a three-dimensional study of (South-2) East Baghdad oil field.
- AL-Sayadi (2015) studied an AVO analysis using selected profiles in the Zubair Formation at South-East Baghdad oil Field, to determine the Direct Hydrocarbon Indicator (DHI) in this field.
- Khorshid et al. (2015) conducted a 3D seismic study of the southern part of East Baghdad Oil Field focusing on the Base of Fatha Formation, Central Iraq. Through the analysis of seismic sections and the application of seismic

attributes (instantaneous phase, reflection magnitude, and variance attributes), they identified the presence of a Direct Hydrocarbon Indicator at shallow depths in the Oligocene epoch.

- Khorshid et al. (2017) conducted a three-dimensional seismic reflection study for the Eastern Baghdad oil field. The seismic sections and time slice maps verified that the upper Cretaceous period was influenced by faults. Fault signs ceased within the Hartha Formation and persisted in deeper formations with augmented intensity.

## **1-7 Aims of the Study**

This study is going to select targets that represent (Nahr umr) rock to achieve the following :

- 1- Analysis of the petrophysical properties of the Nahr Umr Formation to assess reservoir quality.
- 2- Update the structural image of Nahr Umr Formation using the 3D seismic data to determine the structural image.