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Petrographic and Geophysical Comparison of Zubair Formation in North Rumaila and West Qurna Oil Fields, Southern Iraq

A Thesis Submitted to the Council of College of Science, the University of Diyala in Partial Fulfillment of the Requirements for the Master Degree in Geology\ Earth Science

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Abstract

Zubair Formation was studied in West Qurna and Rumaila oilfields in Basra City, southern Iraq, as part of Mesopoamian. The lithology of the formation is primarily sandstone and shale with few limestones, throughout the whole sequence in all studied wells (RU-145, R-25, WQ-1 and WQ-3). These sediments were deposited in fluvio-deltaic environments.

Calcite, quartz and kaolinite authigenic minerals have been identified. Four sandstones lithofacies associations, three shale lithofacies associations and clayey sandstone lithofacies associations are encountered. The main diagenetic features observed include silicification, calcitization, dissolution and replacement, kaolinitization and compaction. Enhancement of secondary porosity due to dissolution of feldspars, carbonate cements occurred early in eodiagenesis and in response to progressive burial.

The results of petrophysical analysis of the available log data indicate that the Zubair Formation can be divided into three zones. the upper zone is composed of dominate shale layer with thin lenses of sand, the middle zone is dominate clean sand to silty sand layer with shale, while the third zone is dominated shale layer , also there are a small amount of limestone in different zone. The shale volume and carbonate minerals content increased toward West Qurna oil field in comparison to Rumaila oil field. The enhancement of petrophysical properties was toward Rumaila oil field in comparison to West Qurna oil field. The middle zone of the Zubair Formation indicate the main pay zone in the studied wells, and it Composed of three reservoir units (ZM 1,ZM 2 and ZM3) separated by to impermeable with variable thickness barrier zones (B1 and B2). In well WQ3 the two barrier zone has higher thickens and merge to be one zone and therefore showed two reservoir units ZM 1and Zm 3. The final results of interpretation revealed that the Zubair Formation is producible

oil in Rumaila field especially in RU-145, because high effective porosity and hydrocarbon saturation. Conversely, in West Qurna wells it is non-producible, due to high water saturation and increased of shale content which effect porosity and permeability.

Chapter One

Introduction

1.1 Preface

The Lower Cretaceous deposits in Southern Iraq are extremely valuable due to their significant hydrocarbon accumulations and reservoirs. Southeastern Iraq, in particular, has a high potential for hydrocarbons, with several highly productive fields having been discovered. Zubair Formation is an important reservoir in southern Iraq and neighboring countries (Idan *et al*., 2019), being part of the Late Berriasian-Albian cycle formations. It is notable for its excellent reservoir properties. As the main reservoir of the lower Cretaceous sequences, Zubair Formation is a crucial economic target for high hydrocarbon production in fields such as West Qurna and Rumaila.

Understanding the petrographic and petrophysical characteristics of the Zubair Formation is crucial for optimizing exploration and production strategies. Petrography provides insights into the formation's depositional environment, diagenetic history, and reservoir quality by examining rock textures, mineralogical composition, and sedimentary structures. Petrophysics quantitatively assesses rock properties such as porosity, permeability, and fluid saturation to predict reservoir performance.

1.2 Location of the Study area

The study area includes both the Rumaila and west Qurna oil Fields which located in Basra City, southern Iraq within the Mesopotamian Foredeep of Iraq (Fig. 1.1), it is strategic location and immense resource potential make it a focal point for international oil companies and investors seeking to capitalize on its production.

Rumaila Oil Field is located about 45km Southwest of Basrah City. It is one of the largest oil fields globally in terms of reserves and production capacity. The field covers an extensive area of approximately 1,800 square kilometers, making it a crucial asset for Iraq's oil industry.

West Qurna Oil Field It is one of the largest oil fields in the world. It lies within the Basra Governorate, approximately 65 Km northwest of the city of Basra. The field spans an extensive area, covering around 8,000 square kilometers. West Qurna is renowned for its vast reserves of crude oil, estimated to be several billion barrels. Table (1.1)

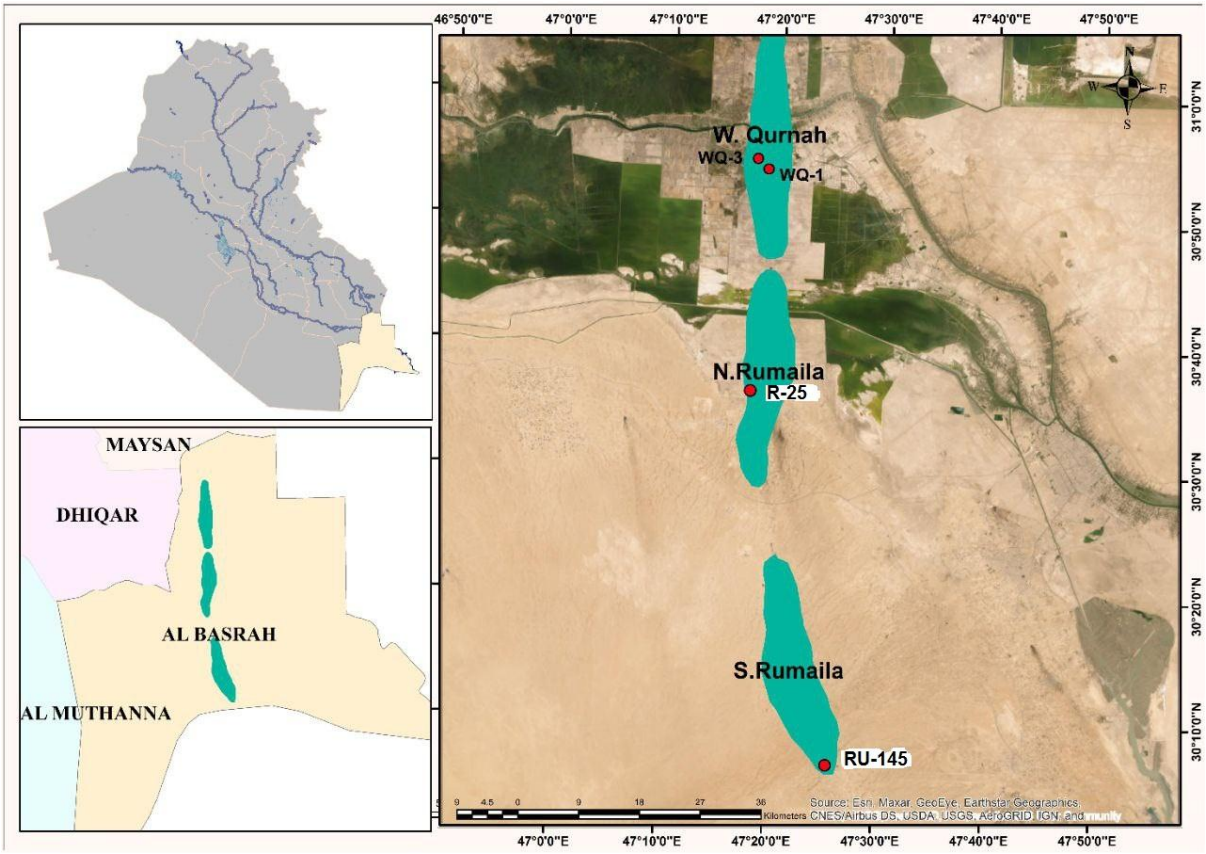

Figure 1.1: Location map showing the Rumaila and West Qurna Fields.

Table (1.1): Coordinates of the studied oil wells with the tops and the thickness of Zubair Formation.

Well Name	Easting (m)	Northing (m)	Top (m)	Bottom (m)	Thickness (m)
WQ-1	720900.03	3420680.42	3074	3425	351
WQ-3	710518.10	3421000.70	3109	3329	220
R-25	719480.00	3389175.00	3114	3321	207
RU-145	743416.00	3330956.00	3209	3447	327

1.3 The main aims of this study are:

1. Petrographic study to compare the nature of the rock's composition and the effects of the digenetic processes on the rocks.
2. Lithofacies interpretation of formation within the studied wells to explain the paleoenvironment of deposition.
3. Evaluation and comparison of the petrophysical properties of the Zubair Formation within the Rumaila and West Qurna oil fields using available log data.

1.4 Geological Setting

1.4.1 Structural Setting

The Rumaila Oilfield, located in the Zubair sub-zone, features several longitudinal folds aligned N-S and NW-SE. These folds are rich in oil reserves in Basra province and are surrounded by narrow linear anticlines that developed during the Late Cretaceous period (Jassim & Goff, 2006). The Zubair Formation, which was deposited in the Early Cretaceous during the AP8 sedimentary cycle (Thamama Group) and the Late Tithonian-Aptian secondary cycle (Barremian-Aptian, 131-113 Ma), spans across Iraq, Kuwait, Saudi Arabia, Iran, and Syria (Harris et al., 2012).

The region is characterized by minimal influence from Alpine movements and orogenic uplift. In contrast, it constitutes an area of Quaternary sediments sinking and buildup bounded by the Takhdad-Qurna basement fault to the north and northeast. The western margin coincides with the edge of the Mesopotamian and stable shelf, which extends south into Kuwait and the Arabian Peninsula (Jassim & Goff, 2006). Aqrawi *et al*. (2010) described the basin as an asymmetric foredeep, particularly in the Neogene succession, where there is significant thickening to the east, most likely due to loading by the Zagros Mountain chain.

West Qurna field lies approximately 65 km northwest of Basra City, Iraq, in the Mesopotamian Basin. The field's development and hydrocarbon accumulation are influenced by its position at the intersection of major tectonic features, including Zagros Fold-Thrust Belt to the northeast and the Arabian Plate's stable interior to the southwest. This transitional zone has undergone significant tectonic activity since the Mesozoic, contributing to the structural complexity of the region (Al-Ameri *et al*., 2015; Jassim and Goff, 2006).

West Qurna oilfield, lied within the Mesopotamian Foreland Basin, is structurally characterized by a series of elongated, asymmetric anticlines oriented in a NW-SE direction, typical of the region. These structures, rich in hydrocarbons, are a result of compressional forces associated with the Zagros orogeny during the Late Cretaceous and Tertiary periods (Jassim and Goff, 2006). The field is one of the most significant petroleum provinces in Iraq and lies in close proximity to other major fields like North Rumaila and Zubair.

They were formed during the AP8 sedimentary cycle of Thamama Group (Tithonian-Aptian) and are regionally extensive, covering large parts of Iraq, Kuwait, and beyond (Aqrawi *et al*., 2010).

The tectonic framework of the region is defined by Takhdad-Qurna fault to the north and northeast, which acts as a structural boundary. This fault system reflects the basin's tectonic evolution, including subsidence and sedimentation in the foredeep basin settings during the Tertiary. To the west, the field is bordered by the stable Arabian Plate shelf, which transitions southward into Kuwait and the Arabian Peninsula (Jassim & Goff, 2006).

In the early Tertiary and Mesozoic periods, the subsidence driving forces are less well-defined, with gradual thickening towards the east (Figure. 1.2).

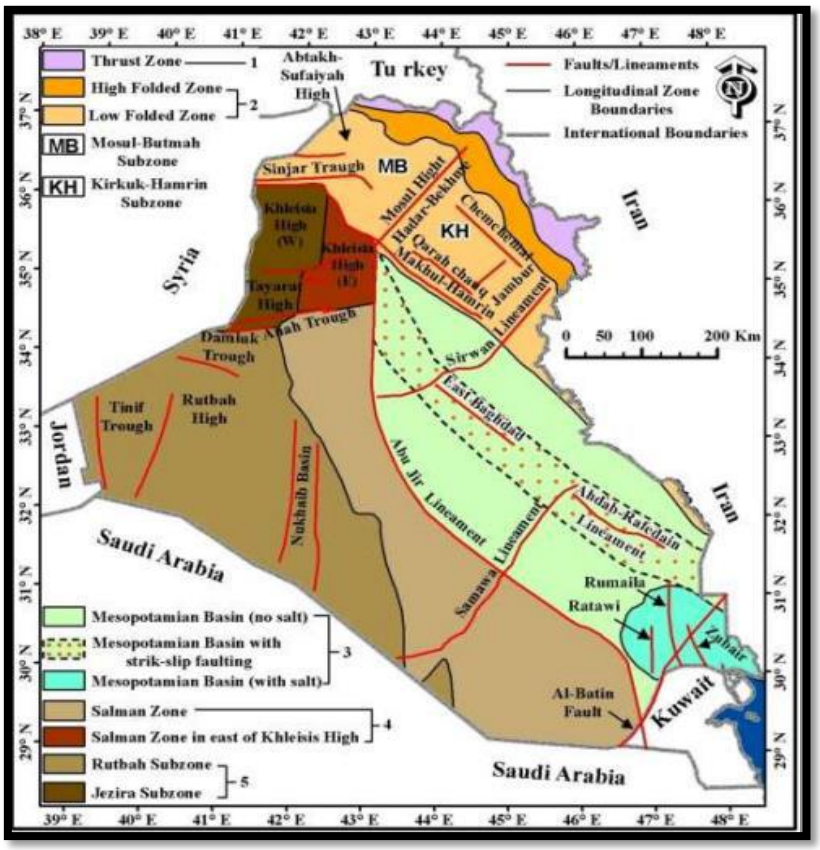

Figure 1.2: Tectonic zones of Iraq, after Jassim and Goff (2006).

1.4.2 Stratigraphic Setting

This formation is primarily composed of oil-bearing sandstone and shale units (Harris *et al*., 2012). In the Zubair oil field, the formation's typical section was identified in the Zu-24 well, which has a thickness of 389.33 m and is divided into five distinct members. These members, which are consistent across the northern Rumaila field and extend to West Qurna field, represent various stages of the field's sedimentary history (Mustafa, 1973). Generally, Zubair Formation comprises siltstone, shale, and sandstone, with the type section being divided into five lithological members: Upper Shale (USM), Upper Sandstone (USSM), Middle Shale (MSM), Lower Sandstone (LSSM), and Lower Shale (LSM) (Figure. 1.3). The proportion of shale in the formation decreases rapidly towards the southwest, while the proportion of sandstone decreases towards the northeast (Jassim & Goff, 2006; Wells *et al*., 2019).

Zubair Formation stands out as a significant reservoir and source rock for oil during the early Cretaceous era. It holds particular importance in Iraq and neighboring regions to the northeast of the Arabian Plate, with its extensive presence noted by Buday (1980). Since the drilling of the inaugural oil well in southern Iraq by an international oil company in 1948, Zubair Formation has garnered substantial attention as a promising oil-bearing geological unit.

Within Thamama Group, encompassing Zubair, Ratawi, and Shuaiba Formations, and belonging to the Late Barremian-Aptian sedimentary cycles, the Zubair units display heterogeneity in organic matter content, impacting permeability, as highlighted by Awadh (2018) and Awadh *et al*. (2019). The region under study lies within the southernmost unit of the Mesopotamian zone, specifically within the Zubair subzone, as depicted in Figure (1.2). Geological processes, such as uplift during the Hercynian movement followed by subsidence post-Late Permian, have shaped this area, as noted by Jassim and Guff (2006).

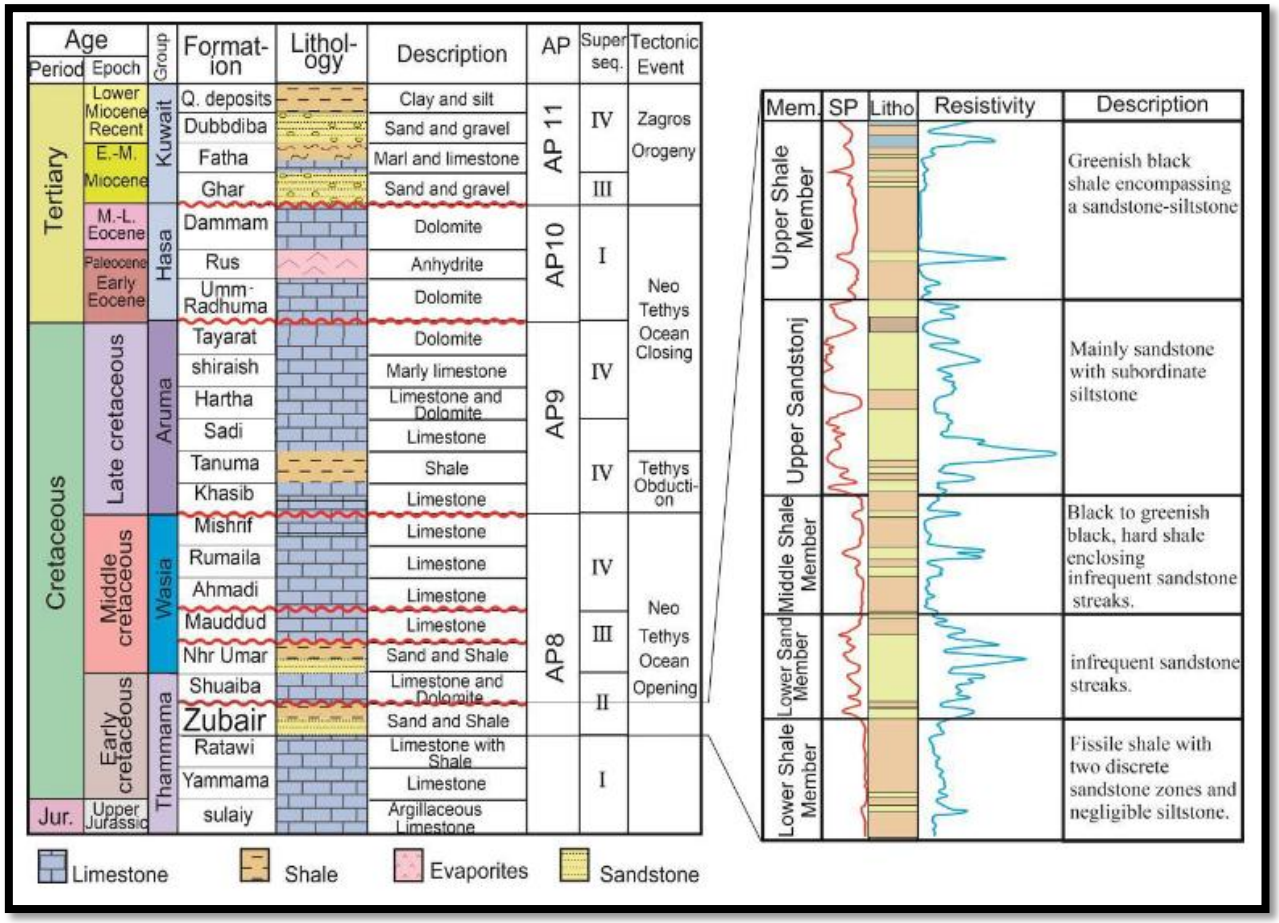

Figure 1.3: left: The composite stratigraphy and lithological section in southern Iraq are modified from Al-Ameri and Al-Khafaji (2014). Right: A stratigraphic section of the Zubair Formation with descriptions of its five components, modified from Aqrawi *et al*. (2010).

1.5 Previous Studies

Zubair Formation, situated within the Mesopotamian Basin of southern Iraq, has garnered significant attention from geologists and researchers due to its rich geological history and potential as a hydrocarbon reservoir. Over the years, numerous studies have been conducted to explore various aspects of this formation, including its stratigraphy, sedimentology, reservoir properties, environments, diagenesis, tectonic setting, and basin evolution. These studies collectively provide valuable insights into the formation's geological characteristics and its role within the broader geological context of the region.

- **Siever 1959;** studied the relationship between pressure solution and the depth in quartz sands. He concluded that the quartz grains in deeply-buried sandstones were more greatly presolved than the shallower ones. This supports the observations in the studied shallowly buried sandstones in which the effect of pressure solution of silicate grains is minor.
- **Bellen, *et al.* 1959;** classified Zubair Formation into five members based on the sand/shale ratio, providing a foundational framework for further research. This classification was instrumental in identifying key stratigraphic units and typical localities within the formation, facilitating subsequent investigations.
- **Rohan 1975; AL-Siddiki 1978;** characterized the formation as representing a deltaic environment, marked by cyclic packages of sediments influenced by marine and fluvial processes. In addition to sedimentological investigations, studies focused on reservoir properties and diagenetic processes within Zubair Formation have shed light on its hydrocarbon potential.
- **Hayes and Boles, 1990;** The occurrence of kaolinite closely associated with altered feldspar grains indicate that the dissolution of feldspars was an important source of ions for kaolinite cement and also that Al3+ was transported only short distance before precipitation.
- **Jawad and Aziz 1993;** identified a series of depositional cycles within Zubair Formation, each representing the growth of a deltaic lobe (construction phase), followed by a hiatus characterized by wave and tidal activity along the delta margin (destruction phase), culminating in a marine transgressive shale that marked the conclusion of the cycle. Their analysis classified the sandstones of Zubair Formation as quartz arenites.

- **Al-Bayati 2001;** documented lateral facies changes within the formation and confirmed inter-tonguing with Ratawi Formation, providing insights into the dynamic geological processes shaping the basin.
- **Al-Kinani 2003;** analyzed reservoir properties, identifying alluvial and deltaic channel sands as primary reservoir rocks, while shale of the delta front and floodplain acted as barrier beds.
- **Al-Ameri, *et al.* 2010;** proposed that oil within the formation originated from Yamama and Sulaiy source rocks, linking its petroleum potential to regional geological processes.
- **Idan, *et al. 2014;*** conducted research on the hydrocarbon potential of Zubair Formation in southern Iraq. The research team discovered that the upper layers of Zubair Formation shale are promising source rocks based on total organic carbon. In the bottom part of the Zubair Formation, the overall carbon concentration is fair.
- **Mahawes, 2015;** improved the subsurface reservoir evaluation of the Zubair Formation by increasing the prediction of petrophysical parameters (porosity, water saturation, and lithology) using a mixture of well log and seismic data.
- **Al-Jaberi and Al-Myyahi 2018;** investigated the Upper Shale Member of the Zubair Formation in the Rumaila oilfield, using Petrel along with Techlog software to determine the petrophysical and electrofacies. The field's porosity model was created with Petrel software, and the permeability was estimated using Techlog.
- **Al-Jafar and Al-Jaberi 2019;** study focused on the Lower Cretaceous Zubair reservoir in the Zubair oil Field. Their research highlighted the sedimentary characteristics of the reservoir using well logging interpretation, an improvement in the relationship between porosity and permeability was observed in the northern part of the field.

- **Al-Zaidy 2019;** proposed a stratigraphic interpretation of the Zubair Formation. He identified sea-level rise as marking the transition to the upper part of the formation and the commencement of deposition of the Shuaiba Formation as shallow marine carbonate.
- **Al-Aradi, *et al.* 2022;** studied The Upper Sand Member of Zubair Formation, and subdivided the formation depending on the productivity per each zone. The net pay for the reservoir unit thickness varied from 5 to 59 meters across all wells, indicating significant hydrocarbon productivity.
- **Rana and Hassan 2023;** Zubair sand rocks are considered to be minerally and texturally mature rocks because they enntain a high percentage of quartz and very few percentages of feldspar and rock fragments, and they contain ultra-stable heavy minerals (eg, zircon, toummaline, rutile) at a bighrate compared to the rest of the types of non-opaque heavy minerals. The shapes of their grains dicates the maturity of its rocks and that it was deposition under a humid or tropical climate.
- **Al-Jawad and Abdullah 2024;** The Economic Evaluation of Various Production Scenarios for Zubair Reservoir in the Kifl Field.

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المقارنة البتروجرافية والجيوفيزيائية لتكوين الزبير في حقلي الرميلة الشمالي و غرب القرنة النفطيين ، جنوب العراق

رسالة مقدمة إلى مجلس كلية العلوم - جامعة ديالى وهي جزء من متطلبات نيل –

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تقدم بها الطالب

ريسان حمود عريب بريسم

بإشراف

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