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Geology of Euphrates Formation and its Economic Importance

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Abstract

This research aims to give an overview of the whole of the Euphrates Formation in Iraq. The deposition of the Euphrates Formation continued for approximately 10 million years, extending from the Early Miocene to the Middle Miocene epoch, including the Aquitanian- Langhian stages (23.3 - 13.82 M.Y ago). The formation is distributed regionally, as it includes about 75% of Iraq and extends to neighbouring countries, as it is equivalent to the Asmari Formation in Iran, while it is equivalent to the Hadroukh and Hofuf formations in Saudi Arabia and Jourdan. Syria is still named the Euphrates Formation, with 200 m thick overlying the Chilou Formation. In central Iraq and Kirkuk, it is equivalent to the Serikagni Formation. The predominant facies of the formation are limestone and marl with dolomization of varying intensity in various locations deposited in a wide range of the marine environment extended from lagoon to open marine. The formation has economic importance; in subsurface sites, it is an oil reservoir, such as in northern Iraq, or an aquifer in western and southern Iraq, in addition to the possibility of using its rocks in multiple industries, most notably in building and construction.

Keywords: Euphrates Formation, Economic, Deposition model

جيولوجيا تكوين الفرات وأهميته الاقتصادية

داليا كريم خضير, صالح محمد عوض *
قسم علم الأرض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

يهدف البحث لى تقديم صورة متكاملة لتكوين الفرات في العراق، استمر ترسيب تكوين الفرات خلال ما يقرب من 10 ملايين سنة، ممتدًا من العصر الميوسيني المبكر إلى عصر الميوسين الأوسط بما في ذلك المراحل الأكويتانية–لانغيان (منذ 23.3 – 13.82 مليون سنة مضت). ويتوزع التكوين إقليمياً، إذ يشمل نحو 75% من مساحة العراق ويمتد إلى دول الجوار، فهو يكافئ تكوين أسمري في إيران، بينما يكافئ تكوين الهدروخ والهفوف في السعودية والأردن. وفي سوريا لا يزال يسمى تكوين الفرات اذ يمتد بسمك 200 متر تموضعا فوق تكوين جيلو. وفي وسط العراق وكركوك يكافئ تكوين سريكاني. السحنات السائدة للتكوين هي الحجر الجيري والمارل مع دلمته متفاوتة الشدة في مواقع مختلفة، مترسبة في مدى واسع من البيئة البحرية تمتد من اللاكون إلى البحر المفتوح. يتميز التكوين بأهمية اقتصادية، ففي المواقع تحت السطحية يكون عبارة

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عن خزان نفطي كما هو الحال في شمال العراق، أو خزان مياه جوفية في غرب وجنوب العراق، إضافة إلى إمكانية استخدام صخوره في صناعات متعددة أبرزها في البناء والانشاءات.

1. Introduction

The Euphrates Formation is one of Iraq's most widespread subsurfaces and surfaces [1]. It has considerable surface extension to the south and southwest of Iraq and crops out in different exposures in the north, west and south of Iraq. The formation is represented by the type locality (8m) in the Wadi Al-Fuhaimi, located in the Anah Trough within the Stable Shelf. The fauna detailed evaluation indicates that the late lower Miocene to Early Middle Miocene is the range age of the Euphrates Formation as the Late-Early Miocene (Burdigalian) is the age of the Euphrates Formation, proved by the *Miogypsina globulina* and *Miogypsina intermedia* [1]. The Euphrates Formation is of economic importance as it is considered a major reservoir in the Ajeel oilfield in north Iraq, in addition to the suitability of its rocks for building, construction and the cement industry [2] and [3]. Many researchers studied the Euphrates Formation in terms of geochemistry; for instance, [4] observed a significant variation in Sr and MgO, with increasing U and V and decreasing Li, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Zr, Cs, Ba, Hf, W, Pb, and Th. Additionally, [4] proposed geochemical criteria that help differentiate between deep and shallow depositional environments. The REEs in the Anah, Euphrates, and Fatha formations indicate fruitful tools that can be used to distinguish between the different depositional environments [4]. The dolomitization effect results in low REE concentrations in the open sea facies where the Euphrates Formation was deposited. Used the isotopic $\delta^{13}C\%$, $\delta^{15}N\%$ organic carbon and total nitrogen content, and atomic C/N ratios isotopes to diagnose and differentiate diverse environments. The organic matter in the Euphrates Formation was derived from marine algae [4]. A rise in or decrease in organic carbon in the Euphrates Formation could be attributed to a partial contribution from terrestrial plants, implying a shallow-depositional environment. The formation is unconformable over the Anah Formation and under the Fatha Formation in Western Iraq. In contrast, in the middle and south of Iraq, its positioning unconformably overlies the Dammam Formation, where the Oligocene is absent and underlies the Nfayil Formation. The Euphrates Formation was used as a case study because it represents a wide spectrum of depositional environments, ranging from the lagoon shallow environments to the open sea environment. This research aims to present the reality of the Euphrates Formation from multiple geological aspects based on field data and published information

2. Materials and Methods

The Euphrates Formation was studied in the Al-Baghdai and Wadi Hajlan in western Iraq and central Iraq's Najaf Desert. The compiled stratigraphic section of the Euphrates Formation in the Baghdadi Area [5] [6] and [7]. The Baghdadi Section was done by [4] and used in this research (Figure 1). The authors studied the Euphrates in many exposures; Figure 2 presents the unconformity separating the Dammam and Euphrates formations. The lower contact of the Euphrates Formation is unconformable to the Middle Eocene Dammam Formation underneath and the Quaternary sediments rising at the Bahar Najaf.

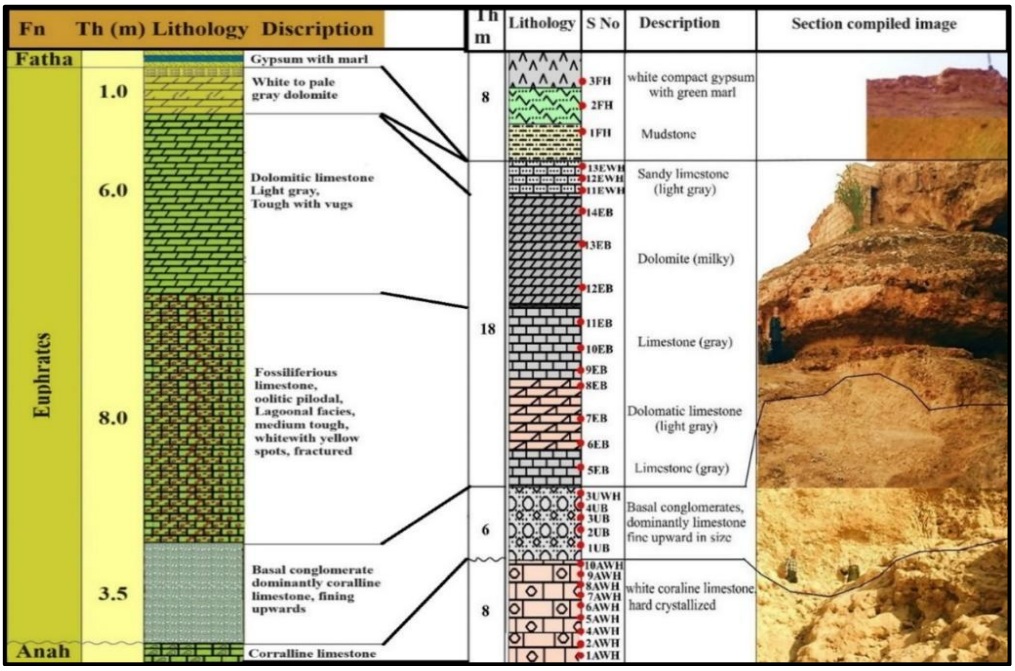

Figure 1: Stratigraphic section of the Euphrates Formation in the Baghdadi area [5] [6] and [7] correlated with the compiled section from Baghdadi [4].

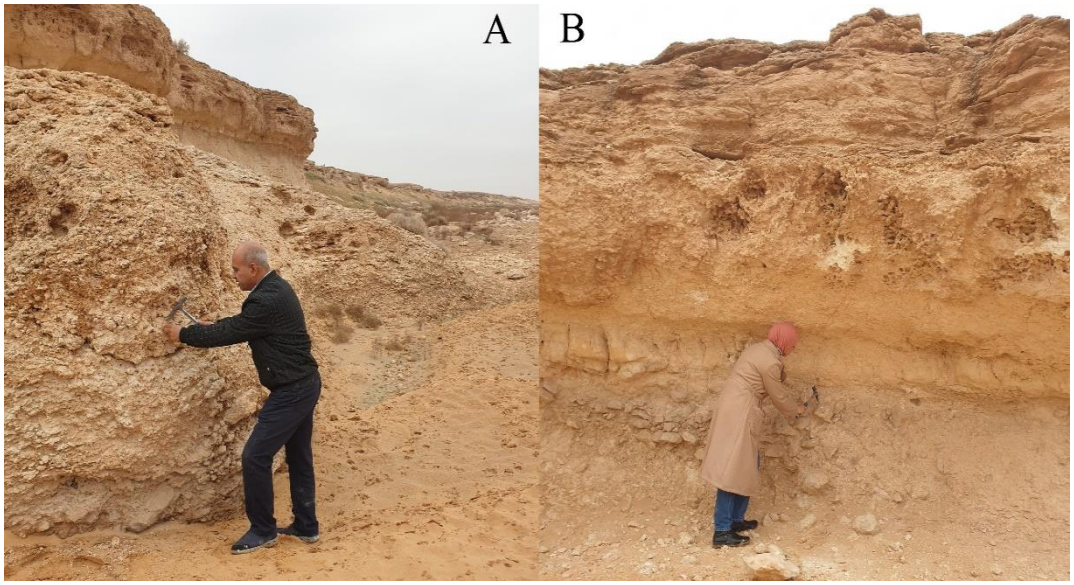

Figure 2: Field study of the Euphrates Formation; A) The Exposure showing the unconformity between the Dammam and Euphrates formations in west Iraq; B) The Upper part of The Euphrates Formation, central Iraq

3. Results and discussion

3.1 Paleogeography and Stratigraphy

The Euphrates (Asmari in Iran), Serikagni, Dhban, Ghar, Jeribe, and Fatha formations were regionally deposited in the Early-Mid Miocene. The Euphrates, Serikagni, and Ghar formations were deposited in the Early Miocene facies in Iraq (Figure 3). The Euphrates Formation is extended to a significant area in Iraq, as shown in Figure 4. The Euphrates Formation is equivalent to the Serikagni Formation in central Iraq and the equivalent of the Ghar Formation in central and west Iraq (Figure 5), and the sand and anhydrite in the Euphrates Formation are possibly tongues with the [8] claimed that the Jeribe Formation is

equivalent to the basal limestone of the Fatha Formation. In the Middle Miocene, the reefal carbonates of the Jeribe Formation were deposited in shallow water. During its activation, the Abu-Jir block was separated into two lagoonal basins, where the Fatha Formation was deposited [8]. The Fatha Formation mainly comprises gypsum in the north and changes to carbonate in the middle and south of Iraq, forming the Nfayil Formation [9].

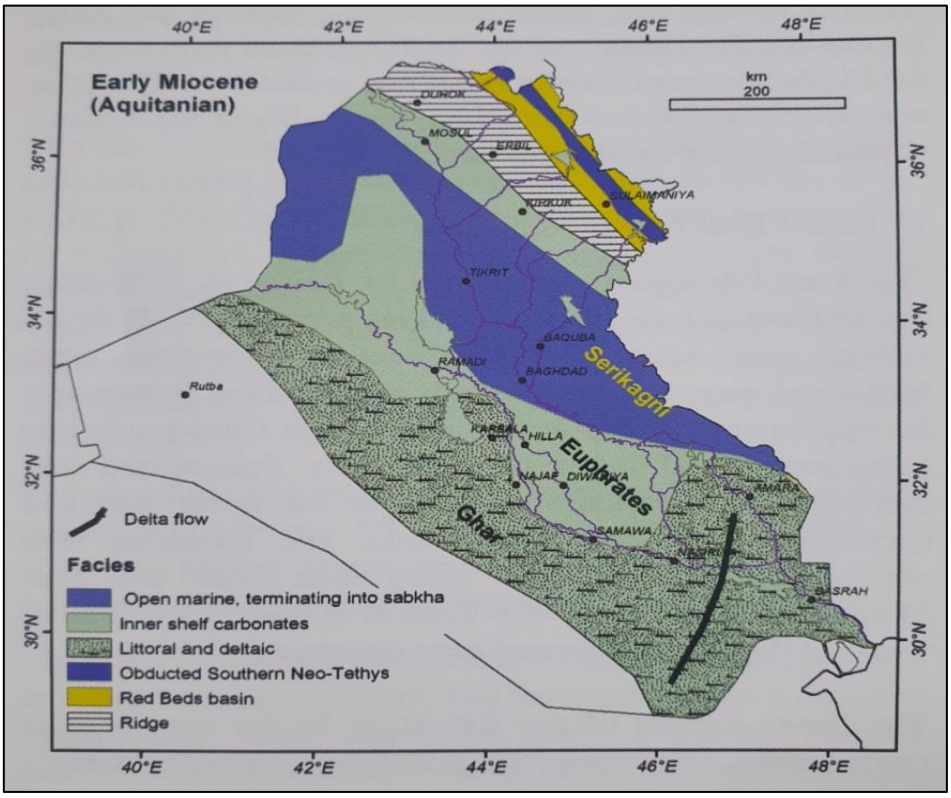

Figure 3: Early Miocene palaeogeography [8]

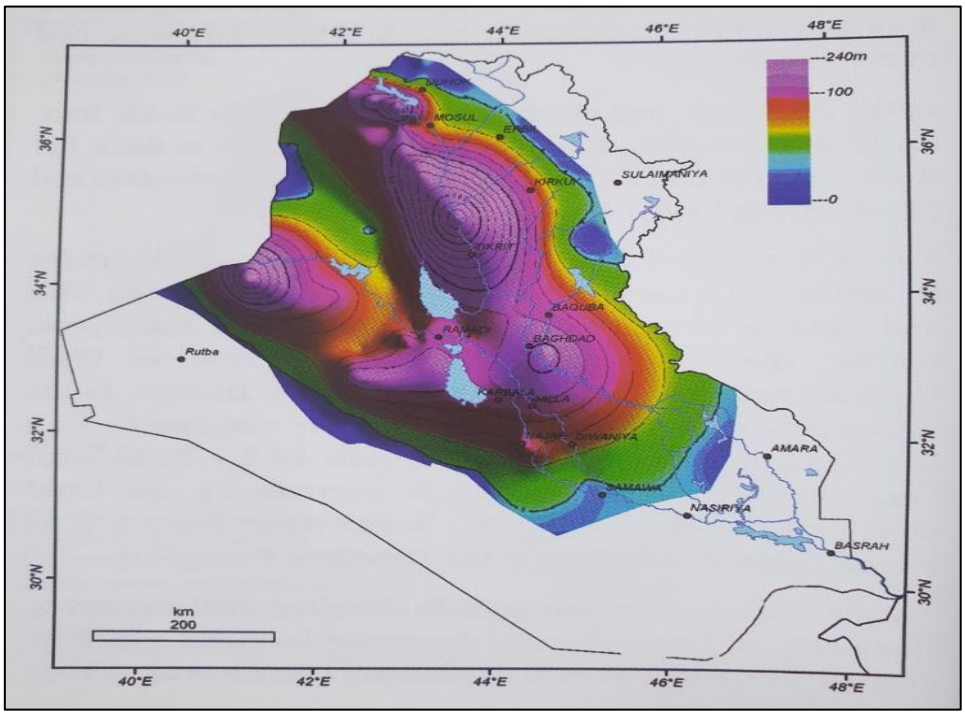

Figure 4: Isopach map of the Euphrates Formation [8]

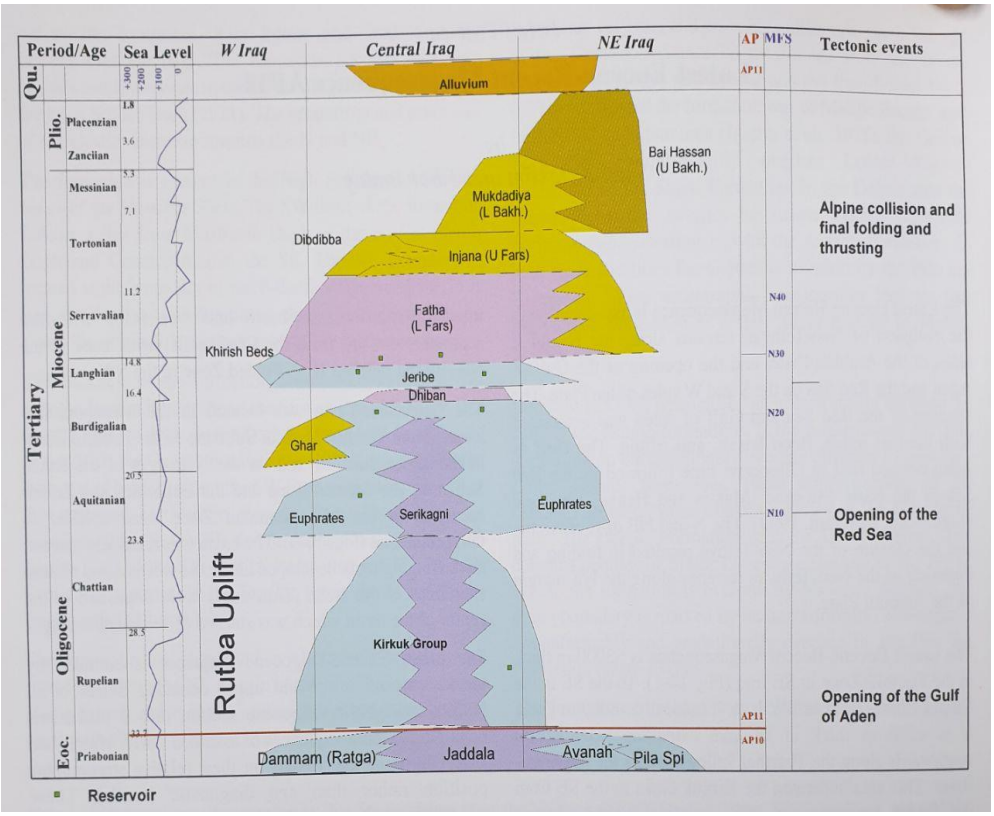

Figure 5: Stratigraphic correlation of the Tertiary displaying the Euphrates Formation in the west central, and northeast of Iraq [8]

3.2 Lithology and Extensions

The type locality (8m) is located in Wadi Al-Fuhaimi, the supplementary type sections 110 m thick represent the lower and middle unite in the Wadi Chabbab, 39 km west of Anah, and 25 m thick 20 km east of Husaiba represents the upper unit of the formation in Wadi Rabi [8]. The average thickness of the Euphrates Formation varies from 60 to 70 m. The type locality is only 8m, but it reaches a maximum of 100 m in the surrounding areas [1]. The Euphrates Formation mainly comprises very variable limestone, massive coralline, shelly, chalky, well-bedded recrystallized limestones, dolomite, dolomitic limestone, and coquinas [10]. Beds of greenish marl, radish, marly sand, silicified limestones, oolitic limestone and conglomerate were found in Anah wells and from surface sections. Anhydrite is also reported in different sites in the Euphrates Formation [1]. The Euphrates Formation is divided into three members: Cavernous and conglomeritic limestone, shelly limestone, and marly and chalky limestones. The upper member somewhere has a disharmonic folding forming, possibly by collapse as a response to the dissolution of the anhydrite and gypsum. However, it is a limestone-dominated unit. It contains a terrigenous clastic admixture near the shoreline supplied from the continent. In western Iraq, the formation is unconformably overly the Anah Formation; it is situated on a basal conglomeratic layer covering the uneven surface of the Oligocene and Eocene formations. It has a conformable lower contact only in areas where the underlying unit is the Serikagni Formation [1]. In Central Iraq, the Euphrates Formation is superimposed on a basal conglomerate of the Dammam Formation, where the Oligocene is missed. The Euphrates Formation is exposed in several areas but not in the type locality because it was covered by the hillocks belonging to the Jeribe Formation [10]. The upper contact is an erosional surface terminated by the conglomeratic horizon. However, the conformable upper contact is located only when the formation overlains and is replaced by the Dhiban Formation. So, with Dhiban, it is conformable, but with the Jeribe, it is not [10].

The Iraq Formation is equivalent to the Ghar, Serikagni, and Dhban formations. In Iran, it is equivalent to Asmari Formation. In Saudi Arabia and Jordan, the Hadroukh and Hofuf formations are equivalent to the Euphrates Formation in age only as they are composed of continental clastics. The Euphrates Formation is 200 m thick, overlying the Chilou Formation. The Euphrates Formation along the Abu-Jir Fault, particularly near the Hit area, contains hydrocarbons seeped upwards along the fault plain [11] and [12]. Many hydrocarbons are expelled from the Jurassic and Lower Cretaceous source rocks. The upward flow of hydrocarbon has continued since the Miocene until now, penetrating multiple geological formations, including the Euphrates and Fatha formations, reaching the surface [13]. The trace element contents in the hydrocarbon-bearing fluids enriched in the Euphrates Formation rather than in the gypsum of the Fatha Formation were detected. It was found that the marine planktonic deposited in an anoxic environment was the source of the organic matter, whereas for a marine anoxic carbonate-shale, marine terrestrial oxic-dysoxic, and terrestrial oxic for the Fatha Formation [12].

3.3 Mineralogy and Geochemistry

The Euphrates Formation's allochems primarily consist of bioclasts. Peloids, ooids, and intraclasts are in lower abundance. The Euphrates Formation fossils include miliolids, algae, ostracods, Miogypsina, and numerous pelecypod and gastropod shells. The Euphrates Formation consists primarily of calcite and dolomite minerals. The carbonates in the Euphrates Formation have undergone various diagenetic processes, including micritization, dissolution, neomorphism, cementation, stylolitization, dolomitization, dedolomitization, and silicification [7]. The Euphrates Formation was deposited on open to restricted platforms, indicating a lagoonal environment with warm and restricted open circulation. Micrite abundance indicates a low-energy, shallow marine environment that may stagnate in certain areas. The Euphrates Formation mainly consists of shallow marine carbonates represented by shelly, chalky, well-bedded recrystallized limestone [7] and [15] with wide subsurface extension. Calcium and carbonate ions are added to this formation as a result of dissolving activities. This formation is located in western Iraq hostig the Euphrates River. Limestone dolomitic limestone with little marl is the main component of the Euphrates Formation, which can be expressed by calcite, dolomite, and clay minerals. The insoluble residue (4.37%) in the Najaf area is higher than the insoluble residue (1.9%) in the Baghdadi Section [2]. Figure 6 shows the representative sample of the Euphrates Formation. It is an excellent way to consider the geochemistry of the Euphrates Formation, which presents three main groups: limestone, dolomitic limestone and clayey marl (Figure 7).

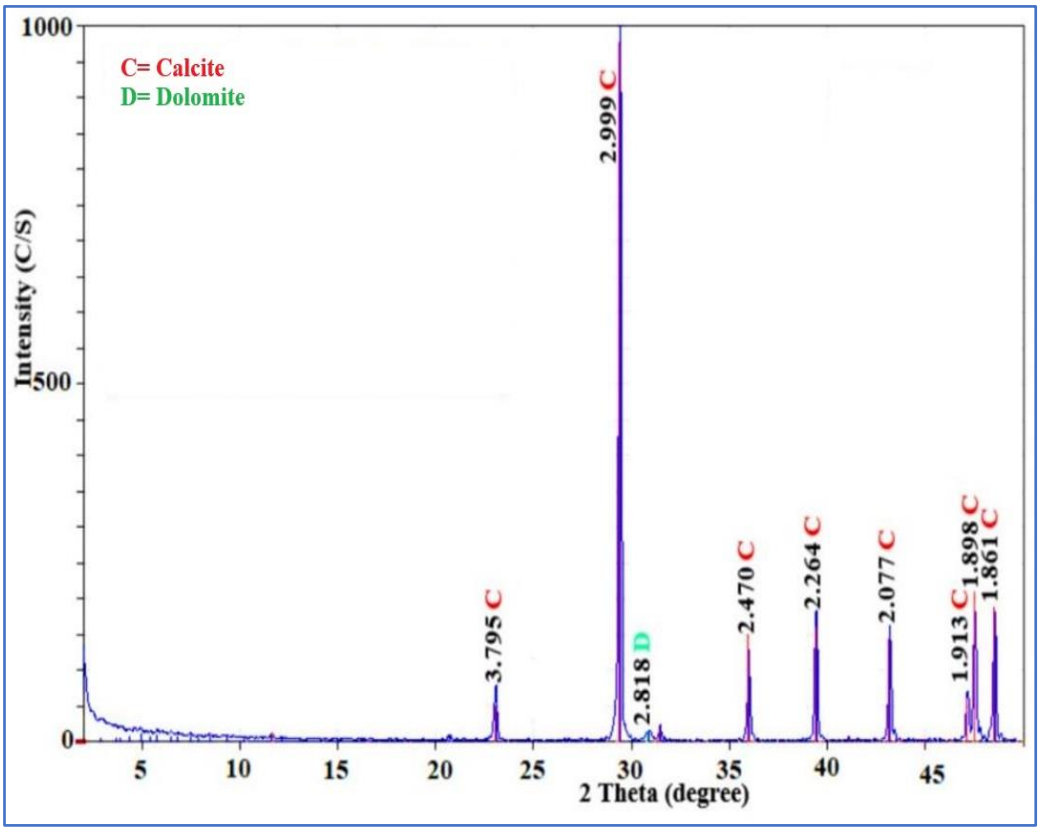

Figure 6: X-ray diffractogram of the Euphrates Formation for the sample collected from the Baghdadi section

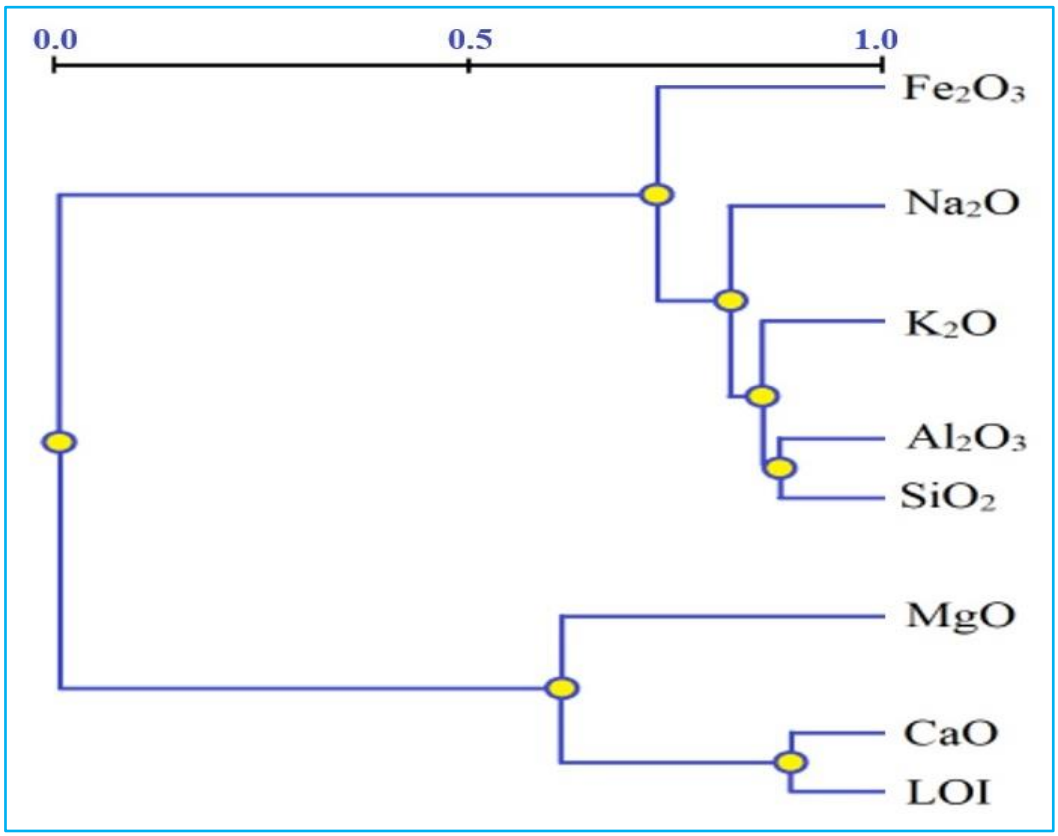

Figure 7: R-mode of cluster analysis illustrates the major oxides in the Euphrates Formation

3.4 Tectonic setting and Depositional model

The wide spread of the Euphrates formation caused the diversity of the sedimentary environment. Many researchers have addressed the environments of this formation, for example, [10], [1] and [8]. The Middle Miocene basin is of shallow water, similar to the Lower Miocene. In south Iraq, the oldest is the Dammam Formation, which the Euphrates Formation unconformably overlies. Later, the Nfayil Formation was deposited dominantly by calcareous sediments equivalent to the Fatha Formation [8]. The Stable Shelf experienced an uplift during the Upper Miocene–Pliocene. Terrigenous clastic sediments, represented by the Injana Formation, were deposited due to this movement. After that, Clastic sediments transported by the Quaternary river systems were deposited in the Dibdibba Formation [14]. According to [1], the Euphrates Formation was formed in lagoons, reefs, and shallow marine waters. The Euphrates, Nfayil, Injana, and Dibdibba formations are helpful evidence for interpreting the tectonics in middle and western Iraq [12] and [15]. In the middle of Iraq, the formations in other areas have different lithological constituents due to the tectonic effect of the Abu-Jir Fault and their position within the depositional basin [16]. In the Al-Baghdadi area, the highland of the Euphrates Formation at the southern Euphrates River was compared to the other side, indicating tectonics. Similarly, in the Karbala-Najaf Plateau, the Euphrates, Injana and Dibdibba formations form a highland plateau, but they were eroded on the opposite side. This is why they disappeared from the western block of the Abu-Jir Fault. The lithology is affected by uplift during L. Miocene [15]. The breccias indicated a transgression, and the overlying beds are middle Miocene belonging to the Jeribe Formation. The Anah, Euphrates, and Fatha formations represent the Late Oligocene-Middle Miocene succession in western Iraq. The depositional model of this succession (Figure 8) can be described as:

a. The L. Oligocene-E. Miocene is represented by the regression due to the uplifting and indicated by the unconformity that separates the Anah and Euphrates formations.

b. E. Miocene represented a transgression due to the regional subsidence forming a lagoon to open restricted platforms. The sedimentary environments of the Euphrates Formation have been divided into a lagoon environment, a back shelf, and an open shelf [17].

c. M. Miocene: The condition of shallow saline marine water was dominant, and the Fatha Formation was deposited as a transgressive-regressive sequence in a broad, shallow foreland basin [18].

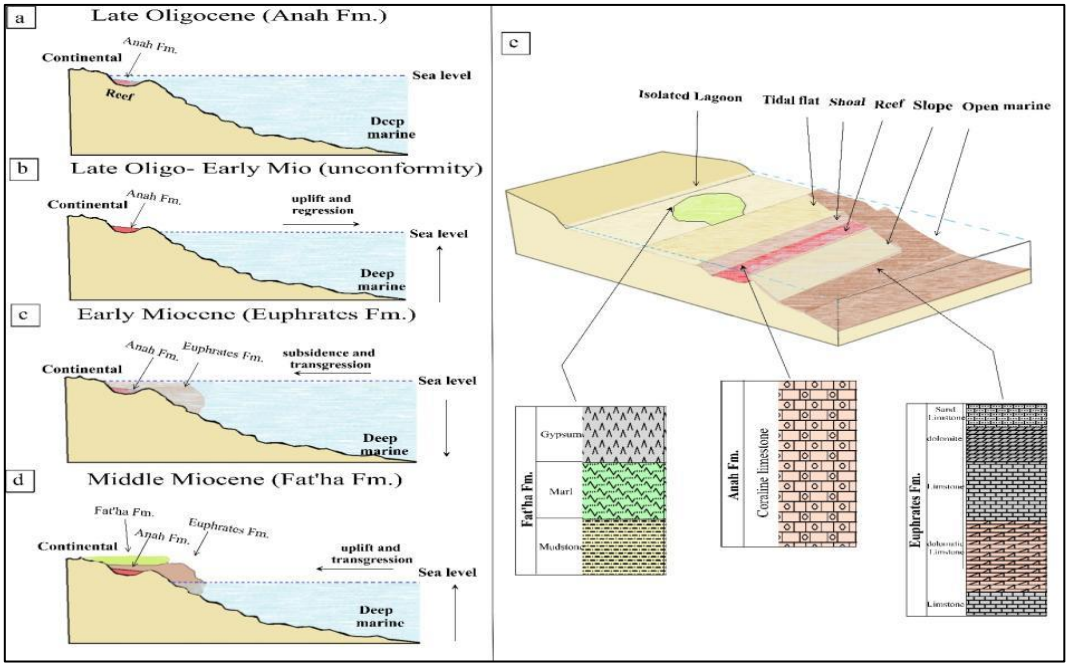

Figure 8: Deposited model of the L. Oligocene – M. Miocene in western Iraq [4]

3.5 Economic Importance

The raw materials of Portland cement are mainly limestone and clay, both of which are available in the Euphrates Formation. The marl layer in the Euphrates Formation in the Bahr Al-Najaf (Figure 9) is suitable for the cement industry as an alternative to clays extracted from arable land, which expressed a step in the correct way to keep arable areas. The marl and limestone in the Euphrates Formation (Lower Miocene) in Bahr Al-Najaf were assessed for Portland cement manufacturing. The marl layer is composed mainly of clay mineral suites (palygorskite, kaolinite, montmorillonite, and illite); in contrast, carbonates showed the dominance of calcite beside a small quantity of quartz, gypsum, feldspar, and dolomite. The Triangle Block method estimates a potential reserve of 63 million tons of medium-tough limestone in a square area (2×2 km^2), considered a probable reserve [14]. On the other hand, the Euphrates Formation is regarded as a major groundwater aquifer in western and southern Iraq, as it is characterized by abundant water that is often suitable for various uses. The aquifer is situated over the Dammam Formation, which overlies the Umm Er Radhuma aquifer. The hydraulic flow of the groundwater in these aquifers is from the west in Saudi Arabia, generally towards the Western Desert in Iraq to the east [16]. The unconfined Euphrates aquifer becomes confined when the Fatha Formation covers it. This aquifer is a strategic water reserve that can be utilized for irrigation. Due to water scarcity and climate changes, groundwater levels have recently declined in all aquifers, including the Euphrates Formation [19]. The contribution of the Euphrates Formation by adding alkali substances to the Euphrates River and maintaining an acidic function that tends to be slightly alkaline, with bicarbonate acting as a buffer solution, has determined the type of bottom sediments, as the river sediments are suitable for many uses such as abrasive materials. The hydrological system between the Euphrates River and the Euphrates Formation is very important in recharging the Euphrates aquifer [20] and [21]. The formation in some locations in the west of Iraq feeds the river, whereas it is fed by the river in the south of Iraq due to the basin setting [22] and [23].

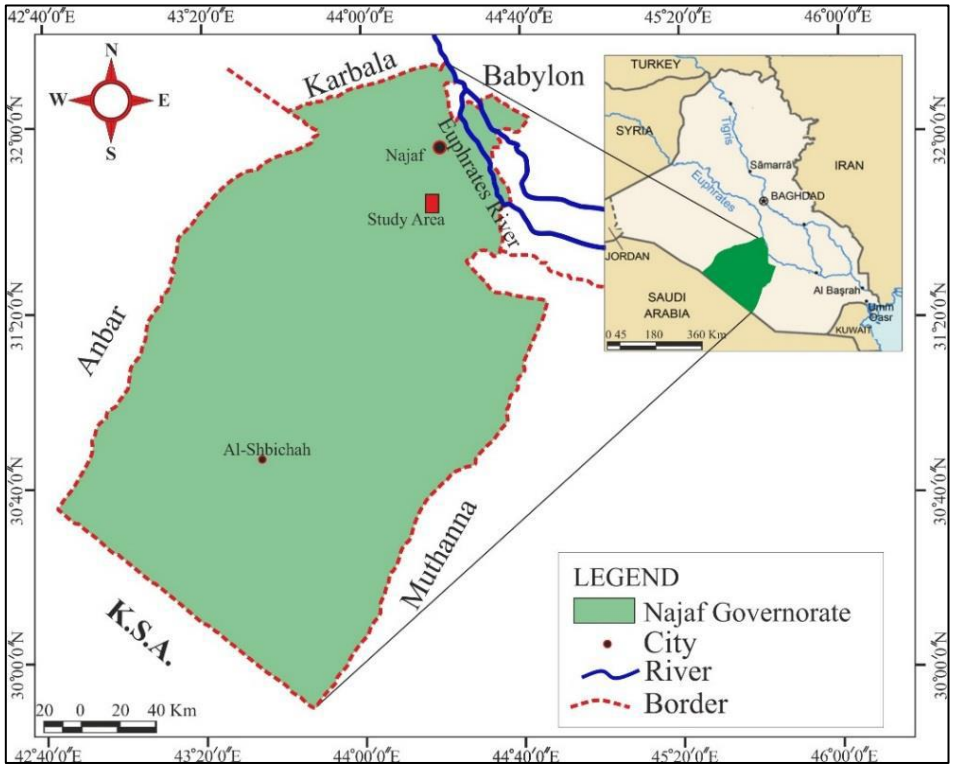

Figure 9: Location map marks the marl layer of the Euphrates Formation in the study area

4. Conclusions

The Euphrates Formation is a wide-ranging formation with surface exposures and subsurface extensions covering most of the area of Iraq in addition to its regional extension. It is usually divided into three units and is characterized by variation in thickness from one area to another. The formation consists mainly of limestone, which has been dolomitized in some locations, with quantities of marl and clay minerals. In western and central Iraq, the formation represents diverse sedimentary environments ranging from lagoon to open marine. The insoluble residue (4.37%) in the Najaf area is higher than the insoluble residue (1.9%) in the Baghdadi Section. Still, it doesn't indicate that the Euphrates Formation was deposited in a more coastal environment in the Najaf area. However, this can be interpreted as the difference in the Euphrates units that have been analyzed. The environment changes from shallow to deep towards central and southern Iraq. The Nfayil Formation, composed of carbonate facies with disappearing gypsum, overlies the Euphrates Formation, while the Fatha overlies it in northern and western Iraq, indicating a lagoon environment. The depositional environment changes from shallow to relatively deep towards central and southern Iraq. The formation was affected by tectonic processes syn and post-deposition, which caused the missing parts of the formation and the appearance of unconformity. The formation is unconformably positioned in western Iraq on the Anah Formation, while it also unconformably overlies the Dammam Formation in central and southern Iraq. The formation has great economic importance, as it varies between being an oil reservoir in northern Iraq and an aquifer in western, central, and southern Iraq. It has many uses, primarily as building and raw materials for the cement industry.

Acknowledgements

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