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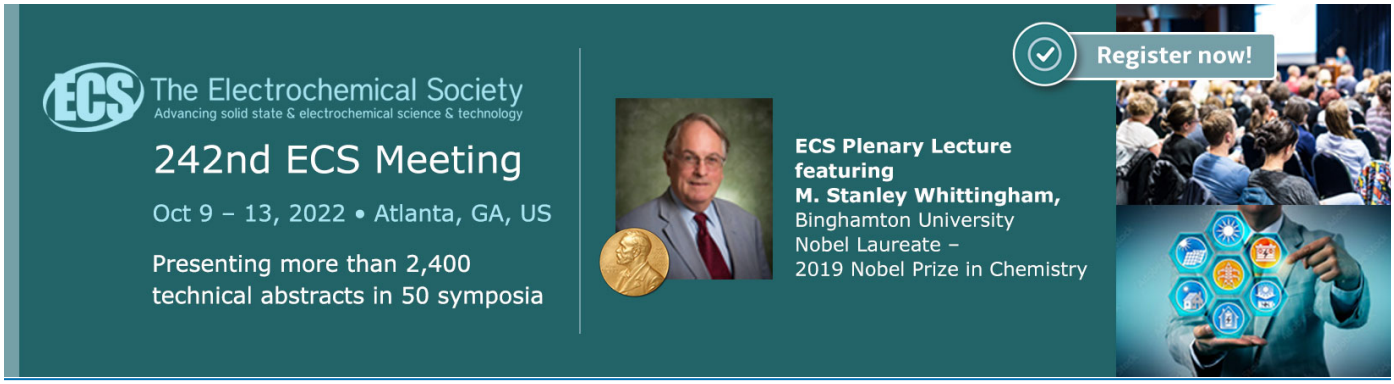

Miocene Stratigraphy of Abu-Jir Fault Zone, Al-Baghdadi Sub-Basin, Western Iraq.

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Abstract. Stratigraphy of Late Oligocene to Middle Miocene age, suggested the carbonates evaporate succession in the area between Heet and Haditha cities within Abu-Jir fault zone has distinguished as "Al-Baghdadi sub-basin" after Al-Baghdadi city. It has NW–SE trending align the western bank of the Euphrates. Al-Baghdadi sub-basin is a local basin, which forms a part of the western marginal of the large foreland Tertiary basin(Zagros Basin) that was created on the Arabian shelf as a result of the collide of Arabian and Eurasian plates. The impact of the Abu-Jir fault on the formations on both regions of the Euphrates has been determined by observing the changes in thickness and lithofacies of the Euphrates, Jeribe and Fatʿha formations. On the western side, the Euphrates and Fatʿha formations were deposited with a relatively a little thickness, with absence of the Jeribe Formation between them and the top of the Euphrates Formation is above sea level. On the eastern side of the Euphrates River, the three formations were deposited with large thickness as compared to the western side, and the top of the Euphrates Formation is below sea level. This is enough to indicate that the western side was uplifting locally due to the activity of the Abu-Jir Fault as a positive flower structure during Miocene, while the eastern side was subsiding. Abu-Jir fault zone behaves as the basin bounding fault that acted like a growth fault. There are also variations in lithofacies between outcrops within Al-Baghdadi sub-basin as revealed from lateral missing or thinning of some layers.

Keywords: Miocene stratigraphy, Abu-Jir fault zone, Al-Baghdadi sub-basin, Euphrates Formation, Jeribe Formation, Fat'ha Formation.

1.Introduction

Many researchers were considered the Abu-Jir Fault Zone as a dividing line between Iraq's stable and unstable shelves, while they differed in extending it beyond Heet city. After passing through Heet vicinity, the fault runs north through Al-Thirthar valley until it meets the Makhul - Hamrin mountain, then turn westward into Sinjar area where disappeared [1 and 2]. The Abu-Jir Fault Zone is never continuous northward; instead, it curves westward in the Heet vicinity to meet Anah Graben and form the Anah-Abu Jir Fault System [3 and 4]. The Abu-Jir fault zone belongs Nabitah fault systems, which formed around 680 Ma during the Late Precambrian Nabitah orogeny. It may be seen in the central Iraqi basement, where N-S trending discontinuities are dragged and deformed along the NW-SE trending Najd faults, along the Euphrates [1]. Abu-Jir Fault Zone is a part of the boundary that composes of many NW-SE trending faults and extends for about 250 Km from west of Razzazah Lake to Anah city [5], which subject to strike-slip movement during the Miocene [6 and 7]. The aim of this research is to know the tectonic effects of the Abu-Jir fault zone on the lateral changes of the lithofacies between the outcrops in the study area, as well as evaluating its effect on the sudden change in the depths of the Euphrates Formation related to sea level between the study area and the area

related to the east region of this fault. The study area extends from Heet city N33°37'02.7" and E42°50'27.4" to Haditha city N34°05'32.7" and E42°21'52.6" which includes four outcrops; Heet, Sahliyah, Al-Baghdadi and Haditha that compare with two subsurface well sections;Melh-Tharthar- 1 -Mh)1-and Falujah (1Jir Fault -SE trend that covers the northern part of the Abu –wells. It has NW Zone, along the western bank of the Euphrates River (Fig.1).

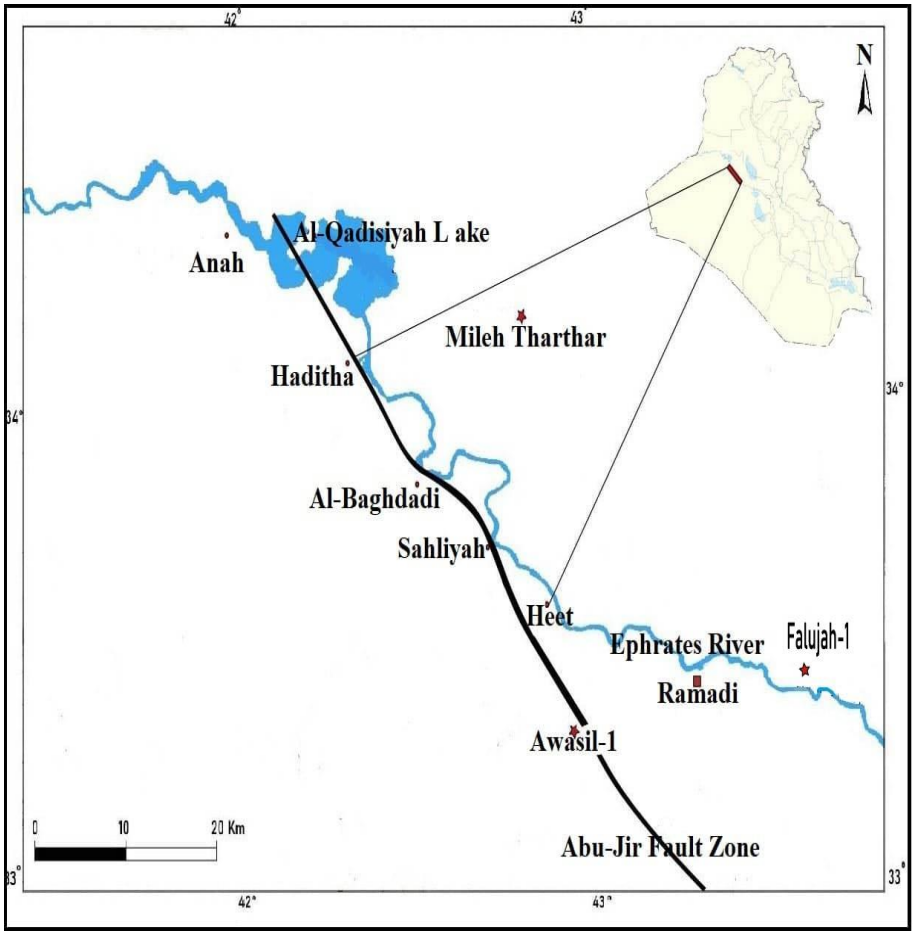

Fig.1. Location map of the study area.

2. Materials and Methods

The present study was achieved on the best lithological outcrops that appear in an integrated manner in terms of horizontal and vertical extension align the western bank of the Euphrates, which includes: Heet, Sahliyah, Al- Baghdadi, and Haditha as well as two subsurface sections: Melh -Tharthar-1 (Mh-1), and Falujah-1 wells. ArcGIS v. 10.4.1 Software used to lay out a geological map of the study area, and RockWare Software to draw a 3D stratigraphic model of the Euphrates Formation.

3. Stratigraphy

The area of study is flat terrain and gently sloping, with a gradient of 5 m/Km, towards east and northeast. The Strata are approximate horizontal which have gentle dip northeast ward, reaches (1–2) degrees [8]. The exposed rocks in the study area have age ranging from Oligocene to Middle Miocene.

Generally, the oldest rocks are referred to Sheikh Alas Formation (Early Oligocene) exposed in Ain Al-Asad valley unconformably with Euphrates Formation [9], whereas only the upper contact of Anah Formation (Late Oligocene), is exposed unconformably below the Euphrates Formation in Haditha section. The present study focused on the Euphrates and Fat'ha formations, which belong to the Lower and Middle Miocene respectively [2]. The Euphrates Formation is the most common formation in surface and subsurface of the Iraqi Western Desert sequence. It exposed along the Iraqi – Syrian borders where it enters the territory of Iraq and extends eastwards crossing Anah, Haditha, Al-Baghdadi and Heet vicinities. It passes laterally to the Ghar Formation between Nasirriyah and Basrah in the south and southeast [10]. The Euphrates Formation consists of chalky, shelly and well bedded recrystallized limestone [11]. The Fat'ha Formation comprising 2-3 cycles of mudstone, marly limestone, and gypsum in the Heet-Kubaisa area [12]. Al-Baghdadi sub-basin forms a part of the western marginal of the Zagros foreland basin, its NW - SE trending (Fig.2) These formations are outcrops within Al-Baghdadi Sub-basin which is thin because it represents a marginal basin.

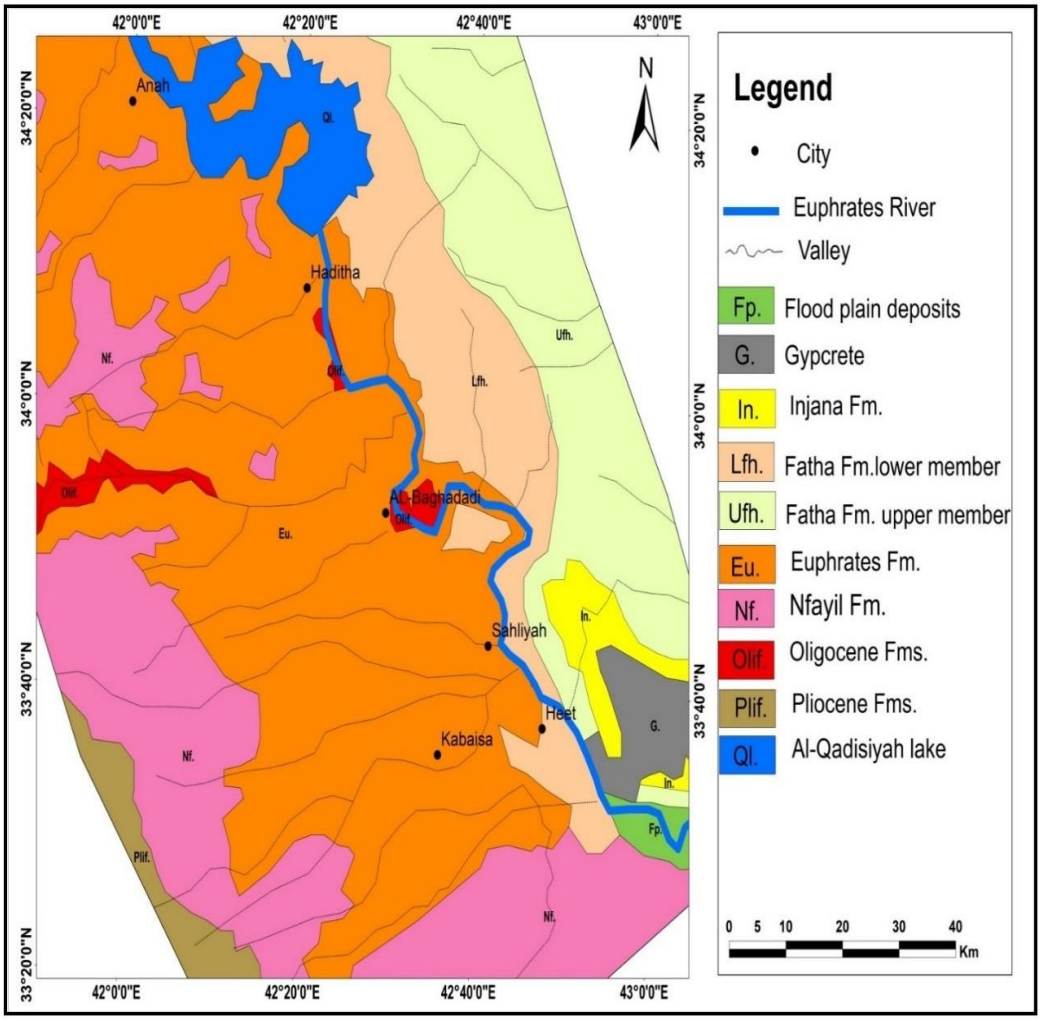

Fig. 2. Geological map of the exposed stratigraphic units within the Al-Baghdadi sub-basin, (modify from GEOSURV Geological map of Iraq 2000).

3.1 Heet Outcrop Section

The Heet section was measured in detail at (N33°. 37'02.7", E42°50' 27.4"). The total thickness of this section is approximately 12 m, as it turns out which has one lithological sequence, represented by the Fat'ha Formation, which have age of the Middle Miocene (Serravallian), according to its position in the stratigraphic column in Iraq.

Through the field study, the litho-stratigraphic sequence (Fig.3), consists of four layers from bottom to top. The bottom layer consists of yellowish to reddish silty claystone with intercalation of siltstone, which a thickness of 2 m. The topping layer consists of layers of marly limestone, with very thin layers of secondary gypsum alternating Periodically which at a thickness of 4 m. It is topped by the third layer, made of greenish to yellowish marl, with intercalation of anhydrite, weathered in places, which a thickness of 2 m. It is topped by the fourth layer, which appears at the end of the sequence, which consists of hard gypsum rocks white colour which a thickness of 4 m, and contains hydrocarbon Seepages. These hydrocarbon Seepages come out through cracks and fractures in the gypsum layer, and after their exit into space, they will become very dense due to the escape of liquids and gases.

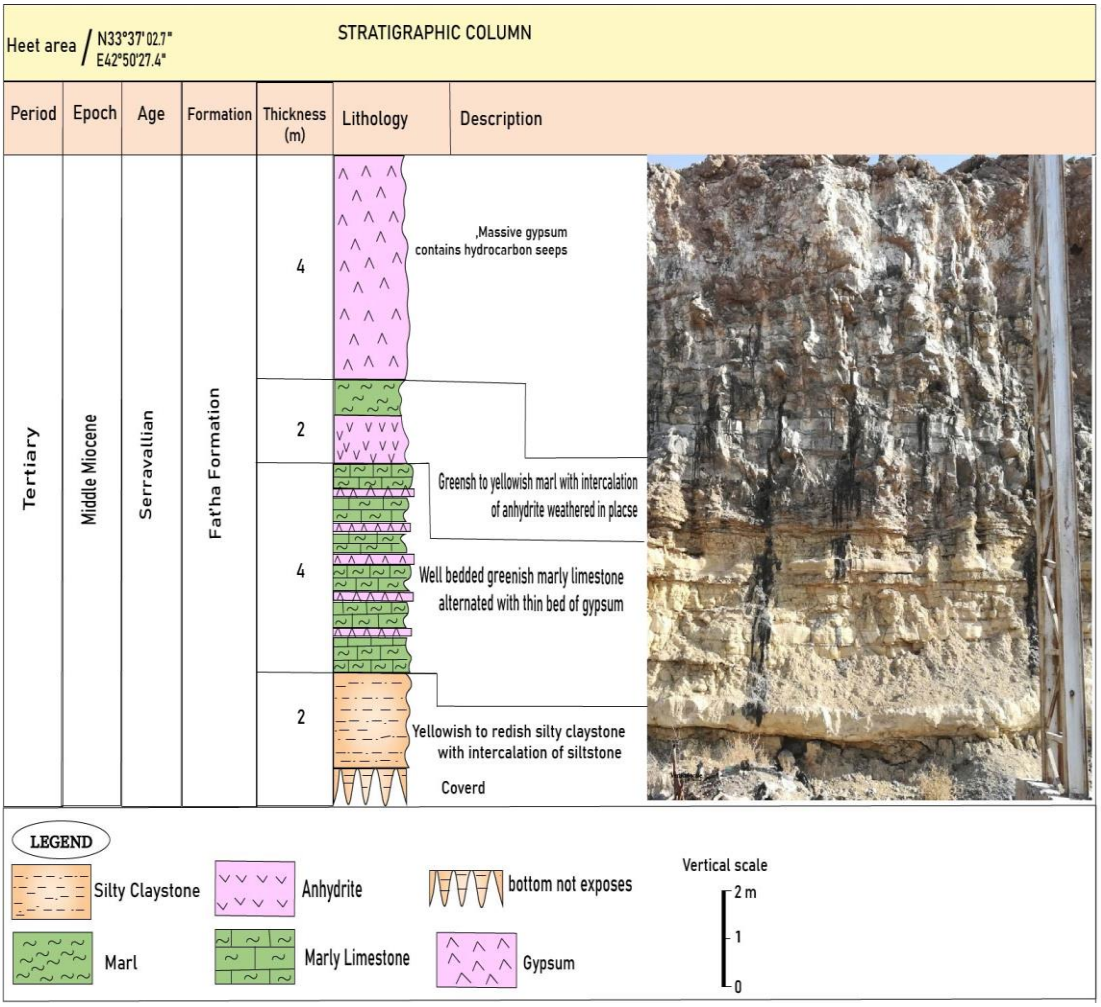

Fig.3. Lithostratigraphic section in Heet area.

3.2 Sahliyah Outcrop Section

The Sahliyah section was measured in detail at (N33° 34'13.8", E42°42' 40.2"). It is located to the northwest of the Heet section, approximately 18 km away from it. the total thickness of this section is approximately 22m. It was found to be represented by the two formations, the Euphrates Formation, which refer to the Early Miocene (Burdigalian) and the Fat'ha Formation, which refers to the Middle Miocene (Serravallian).

Through the field study, the litho-stratigraphic sequence (Fig.4), the lower contact of Euphrates Formation is missing, the lower part of the formation is the unit of basal conglomerate which has thickness 3m. It consists of limestone pebbles, light grey, angular shape with relatively small diameters, resulting from the weathering processes of the rocks older in their places, not continuous along the section. the layers above the basal conglomerate are unit of 17m limestone, that consists of three parts. The lower part consists of light grey, massive, recrystallized limestone, light green marly to marly limestone, and yellowish-white chalky limestone. The middle part consists of well-bedded green marly limestone, light grey slightly oolitic limestone, and dolomitic limestone. The upper part consists of grey fossiliferous limestone. The uppermost part of the Euphrates is hardground surface, which is consists thin layer of the hard, boring, and burrowing dolomitic limestone which has thickness 1m (Plate.1). Which are represent intervals of time during which sedimentation did not take place, cement precipitated, and specialized faunas flourished. Most researchers agreed that the formation process of the hardground leads to the formation of discontinuity surfaces or omission surfaces [13]. These surfaces represent a hiatus between the sedimentary layers located below and above it [14]. The hardground did observe on the top Euphrates Formation in the Sahliyah outcrop, which could indicate a time gap by missing the Dhiban and Jeribe formations, so we prove that the hard ground surface is the unconformity boundary between the Euphrates and Fat'ha Formations. The Fat'ha Formation is located unconformable above the Euphrates Formation. It consists of green marl with thin layer of secondary gypsum which has thickness 1m. Generally, this outcrop is characterized by many local geological structures such as folds, faults, joints, and undulation.

Plate.1. Hard ground unit at the top of the Euphrates Formation, which represents the boundary with the Fat'ha Formation in the Sahliyah section.

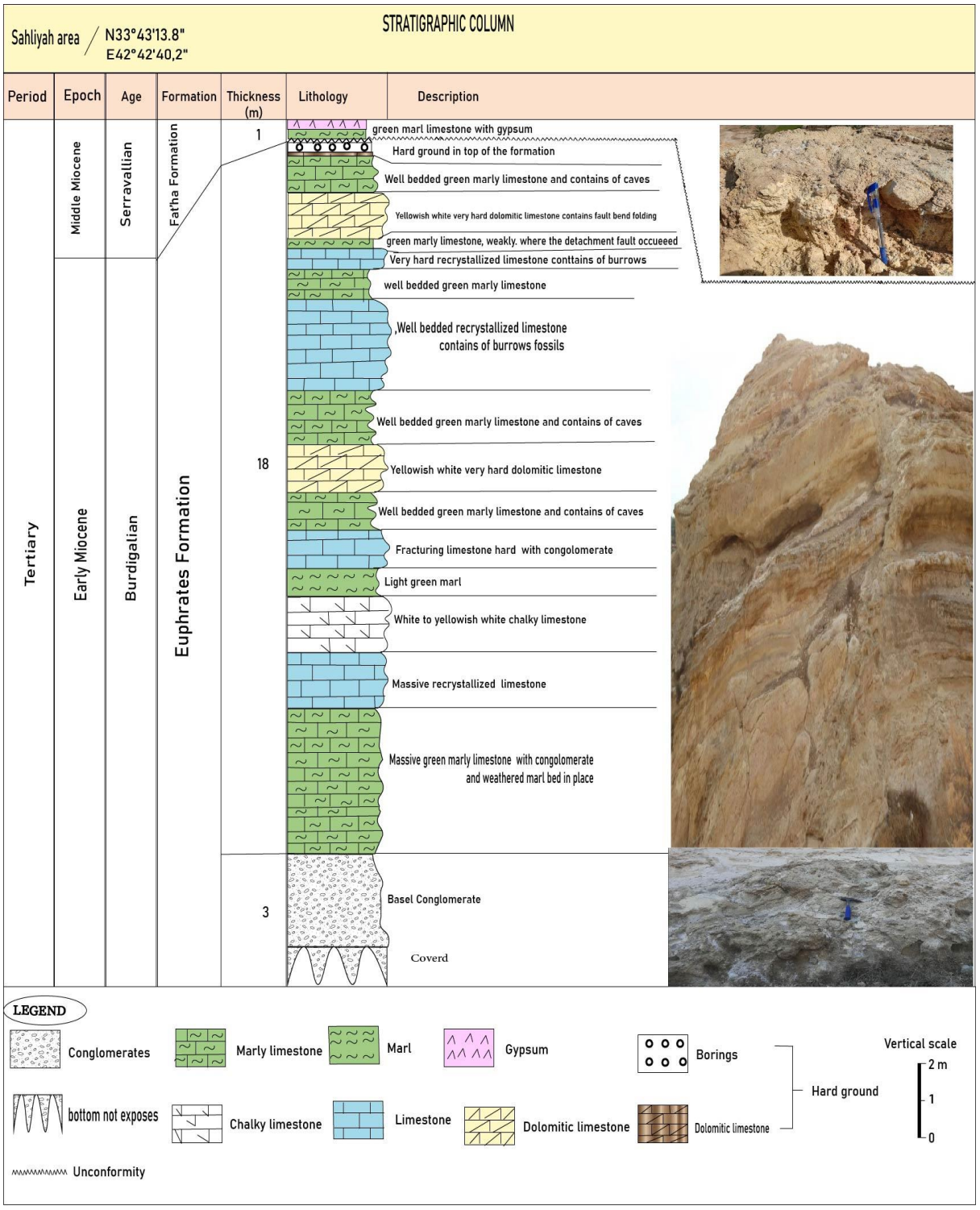

Fig.4. Lithostratigraphic section in the Sahliyah area.

3.3 Al-Baghdadi Outcrop Section

The Al-Baghdadi outcrop was measured in detail at (N33° 51'43.7", E42°31' 55.3"). It is located to the northwest of the Sahliyah section, approximately 28km away from it. The total thickness of this section is approximately 25m. It was found to be represented by the two formations, the Euphrates formation, which refers to the Early Miocene (Burdigalian) and the Fat'ha Formation, which refers to the Middle Miocene (Serravallian) In the vicinity of Al-Baghdadi city.

Through the field study, the litho-stratigraphic sequence (Fig.5), the lower part of the Euphrates formation is the unit of basal conglomerate which has a thickness of 6m. It consists of limestone pebbles of varying sizes, light grey, angular shape, and relatively large diameter at the bottom, gradient upward into smaller and more rounded grains, resulting from weathering of older rocks in their places. The basal conglomerate layer is topped by the limestone unit, which has a thickness of 18m, can be subdivided into lower and middle parts. The uppermost part contains highly deformed, undulated, and jointed, called brecciated and undulation unit, which has a thickness of 2m (Plate.2). **[**9] indicated that the lower boundary of the Formation is unconformable with the Sheikh Alas Formation (Lower Oligocene), also indicated that the brecciated and undulation unit may be the boundary between the two Euphrates and the Fatah formations in the Al-Baghdadi area. The Fat'ha Formation is located unconformable above the Euphrates Formation. It consists of green marl with a thin layer of Secondary gypsum and thickness of 1m. The Fat'ha Formation also appears on the hills in the areas surrounding the Al-Baghdadi area, especially the Al-Dulab area. It consists of alternating layers of green marl and white hard gypsum layers. It is also noted that the gypsum layers form different geomorphological features at the top of the hills, Butte, mesa, and plateau, strongly influenced by the weathering processes (Plate.3).

3.4 Haditha Outcrop Section

The Haditha section was measured in detail at (N34° 05'32.2", E42°21' 52"). It is located to the northwest of the Al-Baghdadi section, approximately 42 km away from it. The total thickness of this section is approximately 27m. It was found to be represented by the two formations, the Anah Formation, which refers to the Late Oligocene, and the Euphrates Formation, which refers to the Early Miocene (Burdigalian).

Through the field study, the litho-stratigraphic sequence (Fig.6), the lower part of the section is Anah Formation consists of Coralline, hard recrystallized massive limestone which has thickness of 3m. Above it is the unconformable Euphrates Formation. The lower part of the Euphrates Formation is the unit of basal conglomerate which has thickness of 4m. It consists of limestone pebbles of varying sizes, light grey, angular shape, and relatively large diameter at the bottom, gradient upward into smaller and more rounded grains, resulting from weathering of older rocks in their places. The basal conglomerate layer is topped by the limestone unit, which unit can be subdivided in to lower part contains well-bedded, light grey, highly fossiliferous, recrystallized limestone with thin layers of marly limestone alternately. The middle part consists of white, bedded, chalky dolostone, limestone, and dolomitic limestone with horizons of green marl. the upper part consists of white, massive dolomitic limestone, highly deformed and brecciated. Followed by grey, massive, highly undulated limestone. it is covered by the Nfayil Formation [10].

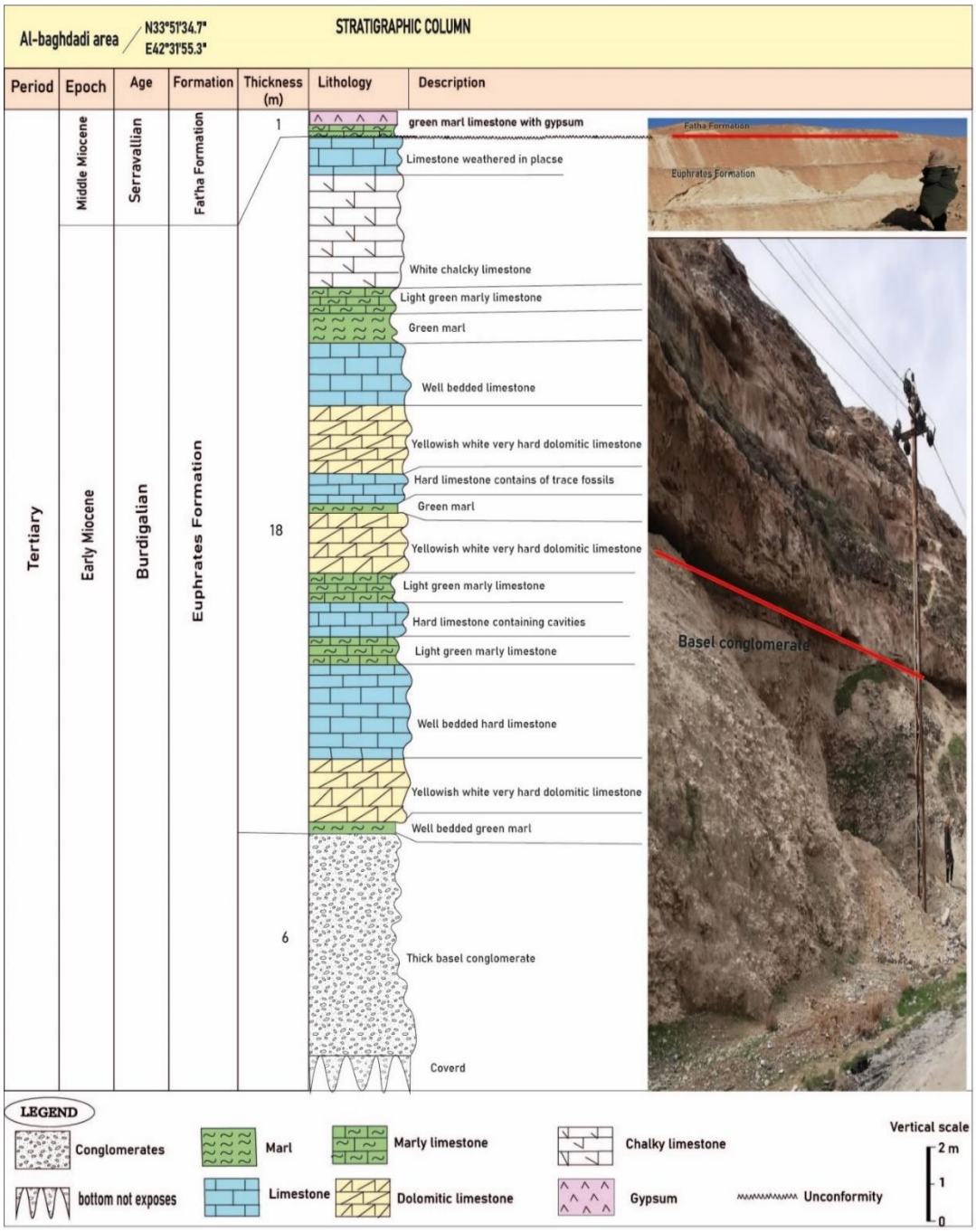

Fig.5.lithostratigraphic section in the Al-Baghdadi area.

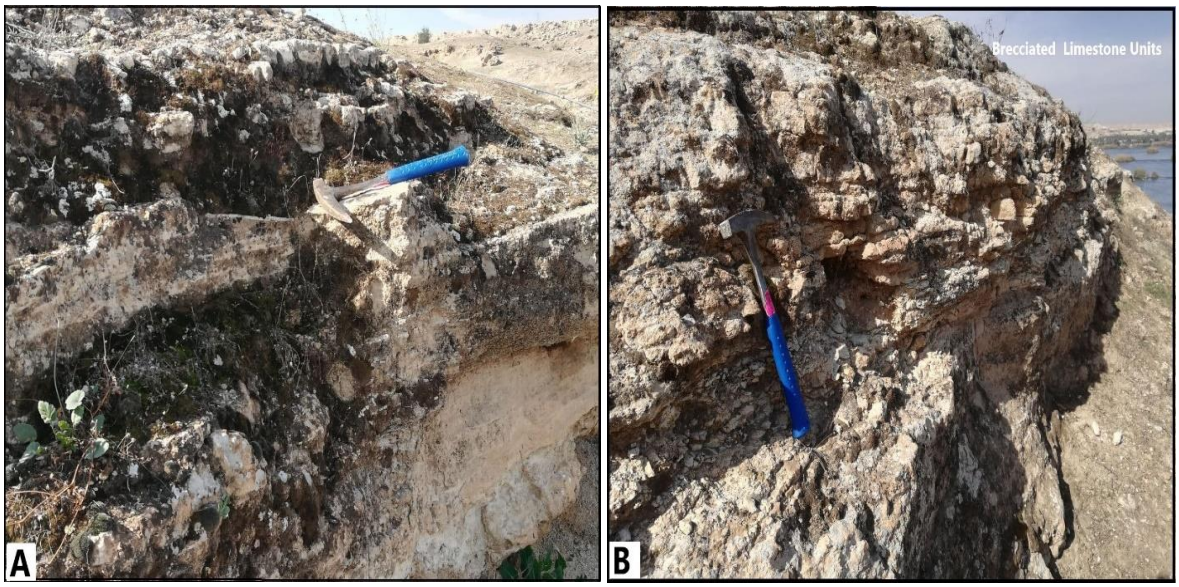

Plate.2. (A)Undulated and (B) Brecciated units at the top of the Euphrates Formation, which represents the boundary with the Fat'ha Formation in the Al-Baghdadi section.

Plate.3. The Fat'ha Formation outcrop in Al-Dulab area.

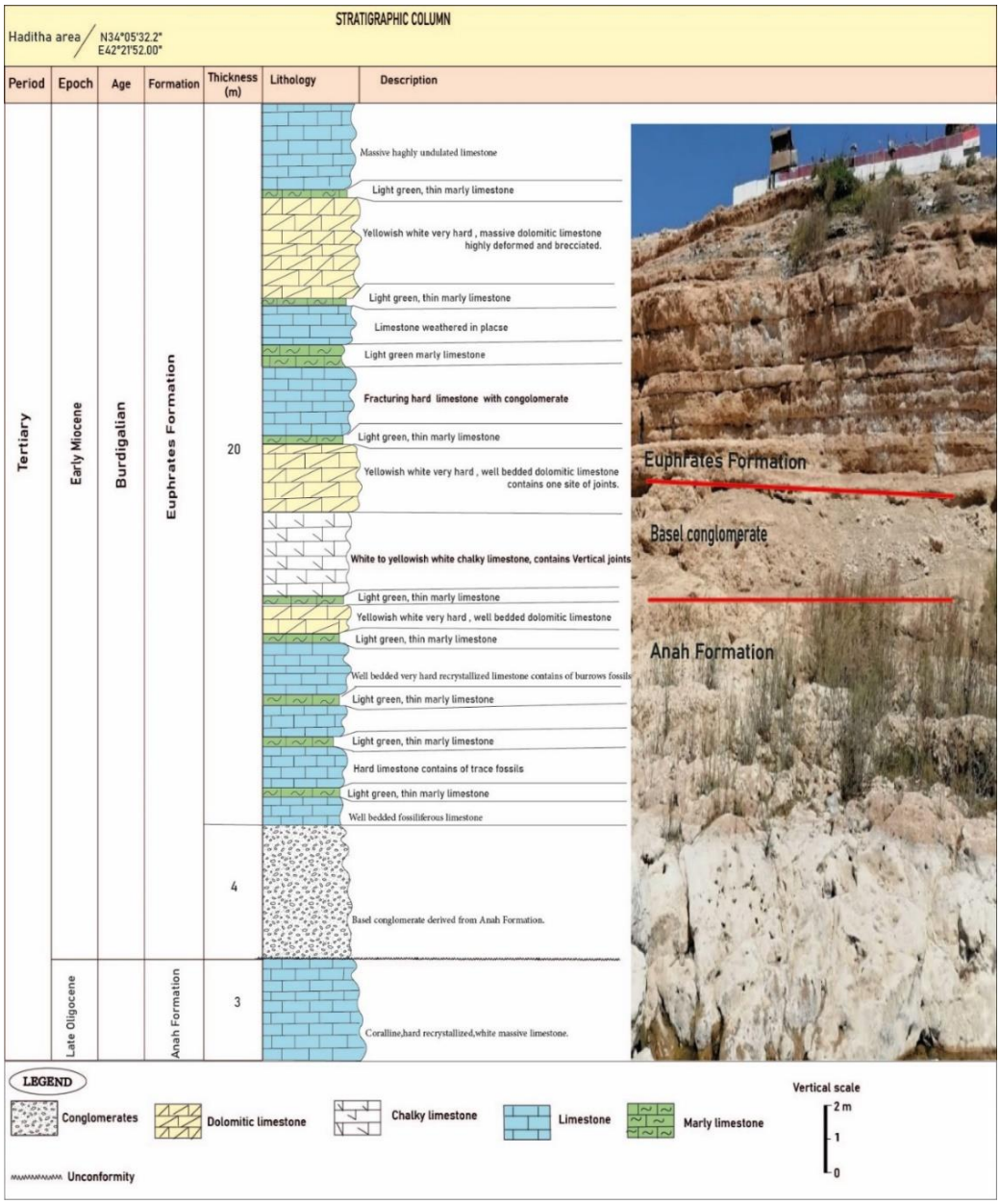

Fig.6. lithostratigraphic section in the Haditha area.

4. Al-Baghdadi Sub-Basin configuration

Al-Baghdadi sub-basin locates in the area that covers the Northern part of the Abu -Jir Fault Zone align the western bank of the Euphrates from the Heet area in the southeast to the Haditha area in the northwest (Fig.1). Al-Baghdadi sub-basin was named after Al-Baghdadi city, which is includes the exposed rocks of Euphrates and Fat'ha formations. Al-Baghdadi sub-basin is located within Abu Jir Fault zone. The tectonic of the fault was controlling the change of the lithofacies and formation thicknesses that deposited in this sub-basin. The Al-Baghdadi sub-Basin is a marginal sub-basin of the main foreland Tertiary basin, which is a NW-SE trend and was affected during the Miocene and Pliocene times. The tectonic activity of the fault developed this shallow marine sub-basin.

The Euphrates Formation, exposed at the sections, consists of basal conglomerate which contains limestone pebbles of varying sizes, light grey, angular shape, and relatively large diameter at the bottom, gradient upward into smaller and more rounded grains, resulting from weathering of older rocks, Oligocene formations, in their places. The upper unit of the formation is limestone unit, while the uppermost part of this unit contains highly deformed, undulated, and jointed beds, called brecciated and undulation units.

Although the distances between the sections within the sub-basin are close but it can be observed that is a large variation in the lithofacies laterally and vertically (Fig.7). Lithostratigraphic correlation between the sections appears the Anah Formation (Late Oligocene) begins to appear on the surface towards the northwest, that indicates the uplifting occurs in this direction, while the southeast area of the sub-basin remains low due to the local activity of Abu-Jir Fault. A relative increasing thickness of the marly limestone layers of the Euphrates Formation toward southeast is good indication of a deep floor related to the northwest of the sub-basin.

Comparing the elevation of the upper boundary of the Euphrates Formation relative to sea level on both sides of Abu-Jir Fault (Fig.8) shows the elevations on the western side are 73.15 m, 91.5 m, and 112.7 m of Sahliyah section, Al-Baghdadi section, and Haditha section respectively, while on the eastern side are -456m, and -256m of the Falujah-1 and Melh-Tharthar wells respectively (Fig.9). The deposition of the Jeribe and the Fat'ha formations with relatively a large thickness to the east of Abu-Jir Fault (Tabl.1), while the Jeribe Formation is absent in study area. It can be considered as indications of very quick subsidence of the eastern side of Abu-Jir Fault Zone during Late Early Miocene and Middle Miocene due to elastic isostasy of the Mesopotamian foredeep. Therefore, it is assumed that fault is a basin bounding fault. It may act as a normal fault or a growth fault. The Fat'ha Formation was deposited as small patches within the Al-Baghdadi sub-basin due to the uplifting occurred along the Abu-Jir Fault during the Middle Miocene, this uplifting prevents deposition of the Fatʿha Formation only as small patches.

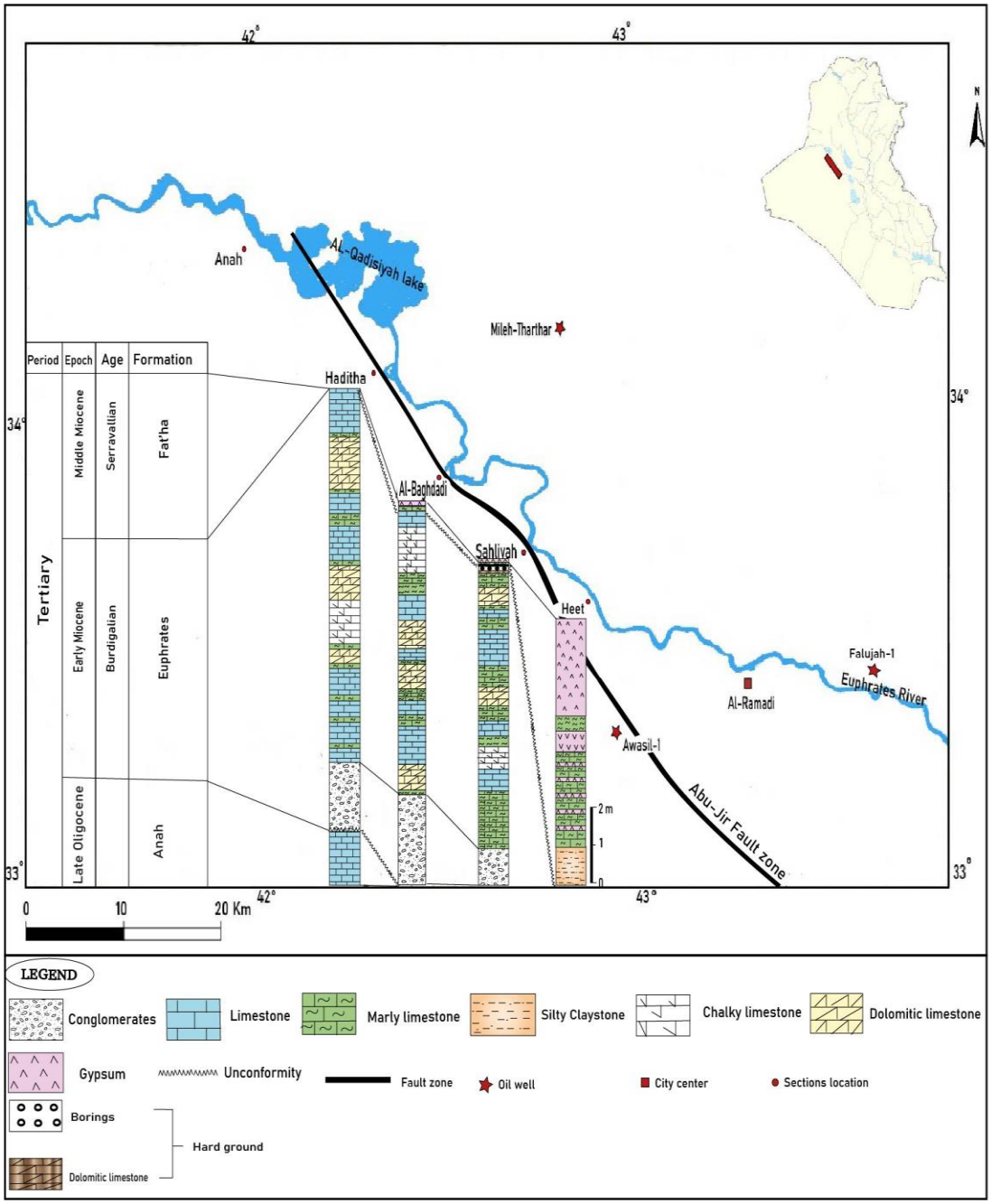

Fig.7. Lithostratigraphic correlation of sections in study area.

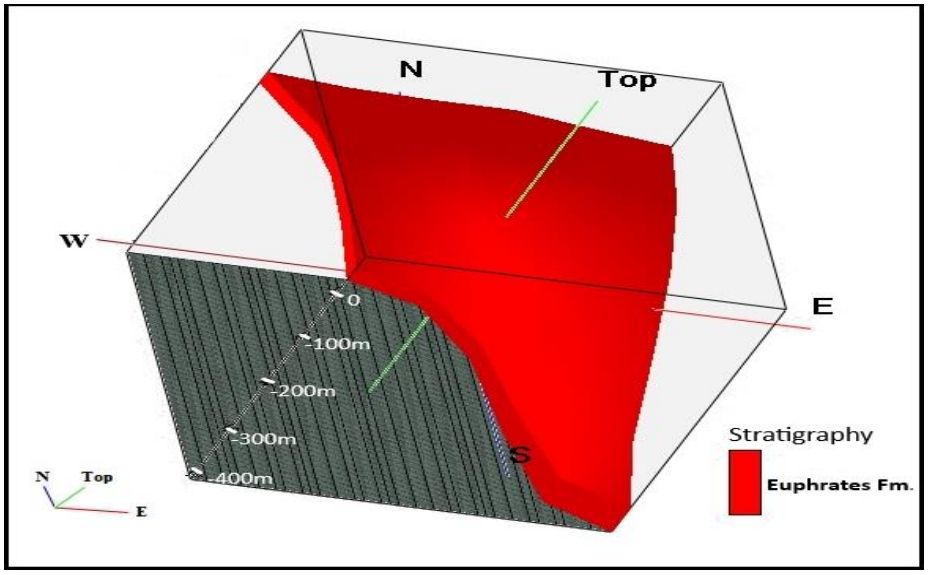

Fig.8. 3D Stratigraphic model of the Euphrates Formation.

Tabl.1 shows the Thickness of Euphrates, Jeribe and Fat'ha formations in study area.

Section name	Type	Euphrates Formation thickness (m)	Jeribe Formation thickness (m)	Fat'ha Formation thickness (m)
Falujah-1	Sub-Surface	57	57	171
Melh-Tharthar-1	Sub-Surface	24	72	184
Heet	Outcrop	---------	--------	+12
Sahliyah	Outcrop	+21	--------	+1
Al-Baghdadi	Outcrop	+24	--------	+1
Haditha	Outcrop	+24	---------	--------

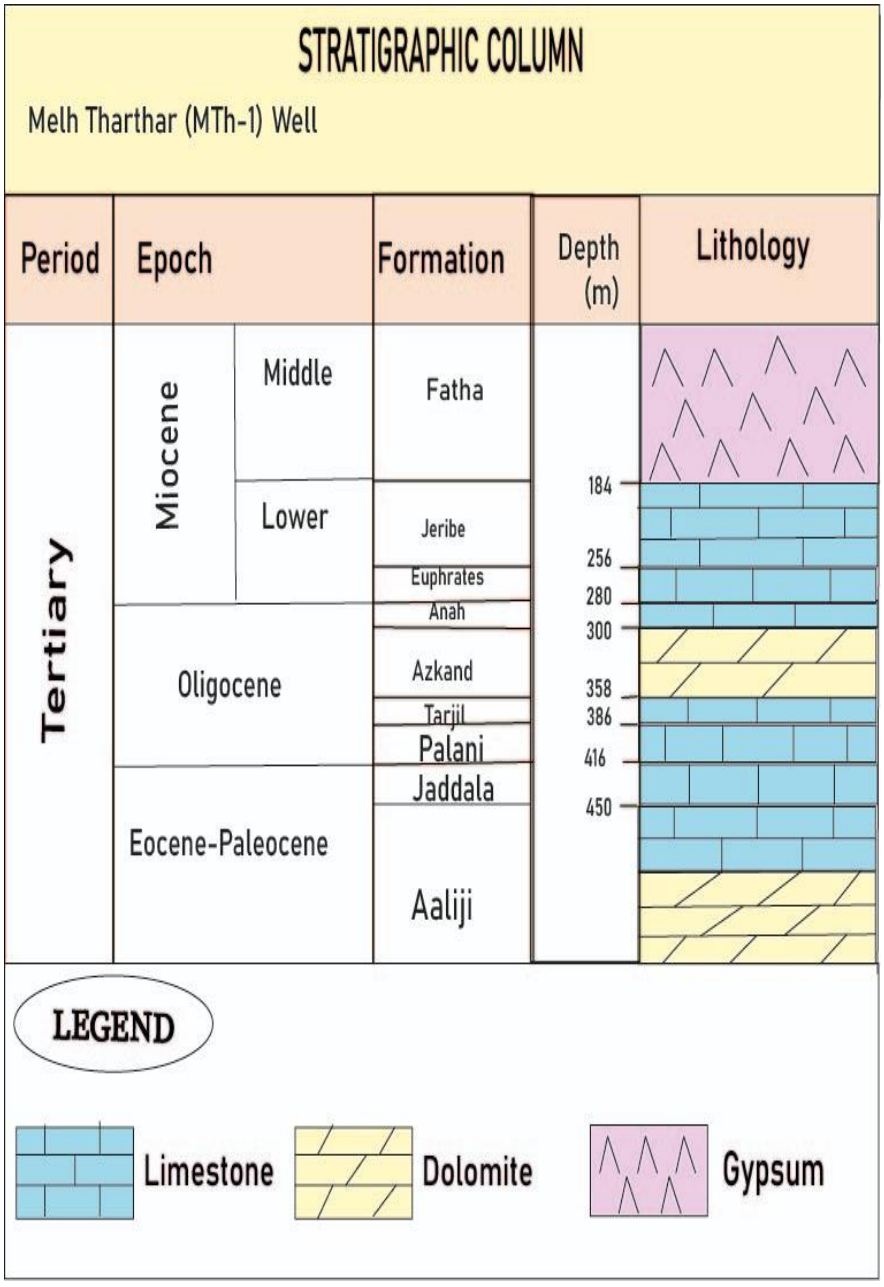

Fig.9. Stratigraphic column of Melh -Tharthar (MTh-1) well, Modified after [15].

5. Conclusion

In the present study, an Early-Middle Miocene sub-basin, located in the west Euphrates River with Abu-Jir fault zone. The following results were obtained through a detailed field study of the outcrops section in the study area (Al-Baghdadi Sub-Basin) as below:

1. The study area represents Al-Baghdadi sub-basin and extends NW–SE trending covering the northern part of Abu -Jir Fault along the western bank of the Euphrates River between the Heet and the Haditha cities.

2. Al-Baghdadi sub-basin is a local, which forms part of the western marginal of the large foreland Tertiary basin) Zagros Basin).

3. Anah Formation (Late Oligocene) begins to appear on the surface towards the northwest, and this indicates that the uplifting occurs in this direction North west, while subsidence took place to the southeast due to the local activity of Abu-Jir Fault.

4. Towards the southeast, we noticed a relative increase in thickness of the layers of marly limestone of the Euphrates Formation deposited in this sub-basin. This means that the environment is deeper than the northwest.

5. Euphrates Formation relative to sea level on both sides of Abu-Jir Fault Zone, note on the western side (73.15 m, 91.5 m, and 112.7 m) represented by the Sahliyah section, Al-Baghdadi section, and Haditha section respectively. On the eastern side (-456, and -256) the Falujah-1, and Melh- Tharthar wells respectively.

6. East of Abu-Jir Fault, Jeribe and the Fat'ha formations are a relatively large thickness with high subsidence while Jeribe Formation is absence west of the fault in study area.

7. It is possible to consider what was mentioned in points (5 and 6) above as clear indicators of very quick subsidence of the eastern side of Abu-Jir Fault Zone during Late Early Miocene and Middle Miocene due to elastic isostasy of the Mesopotamian foredeep. Therefore, it is assumed that this fault is a basin bounding fault. It may act as a normal fault or a growth fault.

8. Al-Baghdadi sub-basin as a result, it is likely that uplifting occurred along the Abu-Jir Fault during the Early Miocene, Fat'ha Formation was deposited in small patches within the at scattered regions. when the Euphrates Formation was deposited but this uplifting did not prevent deposition of the Fatʿha Formation as small patches.

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