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INTERPRETING THE TECTONICS OF THE ABU JIR FAULT, KARBLA – NAJAF PLATEAU USING MINERALOGICAL AND GEOPHYSICAL DATA

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ABSTRACT

The present study is carried out on Abu Jir Fault across the Karbala – Najaf Plateau which is an outstanding fan-shaped geological feature located in the central part of Iraq on the boundary between the stable and unstable shelves. A clear variation of mineralogical composition percentages of quartz, calcite, feldspar, gypsum and gamma ray in both sides of the fault are recorded. The interpretation of magnetic maps; reduction to the pole and depth to basement (RTP and DTB) indicates three depressions, Al-Habbaniya, Al-Razzazah and Bahr Al-Najaf controlled tectonically by a NW – SE basement graben, and the plateau was a part of the subsided area. Gravity field along an ENE – WSW profile across Abu Jir fault indicates an elongated NW – SE positive anomaly of +0.9 mGal whose source is located at a depth of 3 Km, below the plateau, and the uplift is accompanied by faulting. Dibdibba Formation (Pliocene – Pleistocene) in the middle and southern Iraq has been developed in an active basin located along Abu Jir Fault. A large part of this formation is situated on the eastern edge of the Stable Shelf. The western block of the Fault was upthrown after the Pleistocene as a post-depositional tectonic episode forming an elevated area which had since been intensively eroded due to a new tectonism along the Abu Jir Fault. Sharp variations in mineralogy, gamma ray and geophysical parameters have been recorded on both blocks of the fault and are consistent with field evidence and confirm the new tectonics of Abu Jir Fault.

تفسير تكتونية فالق أبو جير عند هضبة كربلاء – النجف باستخدام المعطيات المعدنية والجيوفيزيائية والحقلية

صالح محمد عوض، حيدر عدنان البهادلي و زينة سليم الانكاز

المستخلص

اجريت هذه الدراسة على هضبة كربلاء – النجف، وهي إحدى المعالم الجيولوجية البارزة وسط العراق، الواقعة ضمن نطاق فالق أبو جير على الحد البنيوي الفاصل بين الرصيف المستقر غربا، وغير المستقر (حوض وادي الرافدين) شرقا. استخدمت البيانات المعدنية، والجيوفيزيائية والدلائل الحقلية كوسائل لتفسير بنيوي جديد لنطاق فالق أبو جير. لقد بينت التحاليل المعدنية والقياسات الاشعاعية وجود تغاير في التركيب المعدني للكوارتز، الكالسايت، الفلدسبار والجبس والنشاط الاشعاعي، عبر جانبي الفالق. ومن الناحية الجيوفيزيائية، فقد بينت دراسة المجال المغناطيسي ان منخفض كبير، يضم كل من بحيرتي الحبانية والرزازة ومنخفض بحر النجف، نتج بفعل نشاط بنيوي لانهدام تركيبي في صخور القاعدة على عمق 8 – 9 كم باتجاه شمال شمال غرب – جنوب جنوب شرق وان الهضبة كانت جزء من هذا المنخفض قبل عملية

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الرفع الحاصلة بعد انتهاء ترسيب تكوين الدبدبة (بلايوسين – بلايستوسين). دلت دراسة المجال الجذبي على وجود شاذة متبقية موجبة بقيمة 0.9+ ملي كال وباتجاه شمال غرب – جنوب شرق فسرت على انها مرتفع تركيبي على عمق 3 كم، وهي المصدر المسبب للتهضب، وان عملية الرفع كانت مصاحبة لنشوء فالقين الشرقي منهما يصل السطح ليترك معالم جيومورفولوجية واضحة. ان تكوين دبدبة في وسط وجنوب العراق كان قد ترسب في حوض نشط يقع على امتداد نطاق فالق ابو جير، وان جزءا كبيرا من هذا التكوين، يتموضع على الحافة الشرقية للرصيف المستقر، فيما ارتفعت الكتلة الغربية للفالق بعد فترة البلايستوسين بنيويا بعد ترسيب دبدبة مكونة أراضي عالية تعرضت فيما بعد الى عمليات تعرية شديدة ادت الى ازالة تكوين دبدبة. تم تسجيل تغاير ملحوظ في المعدنية والنشاط الاشعاعي (كاما) والعوامل الجيوفيزيائية تتفق مع الدلائل الحقلية عبر طرفي الفالق وتؤكد النشاط البنيوي الحديث لفالق ابو جير.

INTRODUCTION

The study area is located in central Iraq across Abu Jir Fault Zone including the Karbala – Najaf Plateau to the east, and Razzazah and Dibdibba Depressions to the west. The plateau is fan shaped covers an area estimated by 3171 Km^2 defined by the coordinates: 31° 50' to 32°40' N and 43° 30' to 44° 30' E. It is situated on the boundary separating the Stable Shelf to the west and Unstable Mesopotamia Foredeep Basin to the east (Fig.1). Al-Habbaniya, Razzazah Lakes and Dibdibba Depressions represent the northwestern and southwestern surrounding parts of the plateau respectively (Fig.1). The Plateau is a distinct geomorphological feature located in middle of Iraq between the Mesopotamia Plain and the Western and Southern Deserts (Sissakian *et al*., 2015). It terminates to the east with two sharp cliffs called Tar Al-Say'ed and Tar Al-Najaf. The distinct location of the plateau remarks a valuable observation worth to be studied.

The problem of this study is the contradictions in interpretation of the plateau origin, and how it was formed?. Many previous studies have been conducted on Karbala – Najaf Plateau with different aims. Some researchers attributed this plateau to a large alluvial fan, while others pointed out it was an old delta. Although some researchers have indicated the tectonic role in the formation of the plateau, but no convincing evidence or detailed study has been provided. So, it is believed that there is no detailed evidence of the origin of the plateau. Sissakian *et al*. (2015) mentioned that the top surface of the plateau is covered by alluvial fan sediments, laid down by Al-Khir Valley when merging in a large depression due to the drop in the gradient of the valley. The deposition stopped due to an uplift movement activity in response to the Abu Jir Euphrates Fault Zone. Al-Ankaz (2012) and Awadh and Al-Ankaz (2016) confirmed the Dibdibba Formation is a clastic sediments originated from the Arabian Shield and deposited under flviatile environment. Jassim *et al*. (1984) mentioned out that, it was deposited as extensive sheets probably as large old alluvial fans.

The western edge of the plateau is bordered by Lake Fault system extends from north of Al-Thirthar Lake to the south of Al-Razzazah Lake comprising grabens, horsts and normal faults (Abdul-Jabbar, 2013). The joints occurred within the claystone bed of the Injana Formation are of chemical origin not tectonically (Awadh *et al*., 2013). Field stratigraphy evidence is a one of the tools that was used coupled with the mineralogical and geophysical data for the purpose of addressing the problem. Most middle and west parts of Iraq are covered by rocks of Eocene – Pleistocene ages such as the Dammam Formation (Middle – Late Eocene), Euphrates Formation (Early Miocene), Nfayil Formation (Middle Miocene), Injana Formation (Late Miocene) and Dibdibba Formations (Pliocene – Pleistocene). The Dibdibba Formation crops out in wide areas located within the Stable Shelf in the Middle and southern parts of Iraq. The Injana and Dibdibba formations stand high forming Karbala – Najaf Plateau. The discontinuity of the geological formation with a sudden break in the beds and topography is the main motivation to conduct this study.

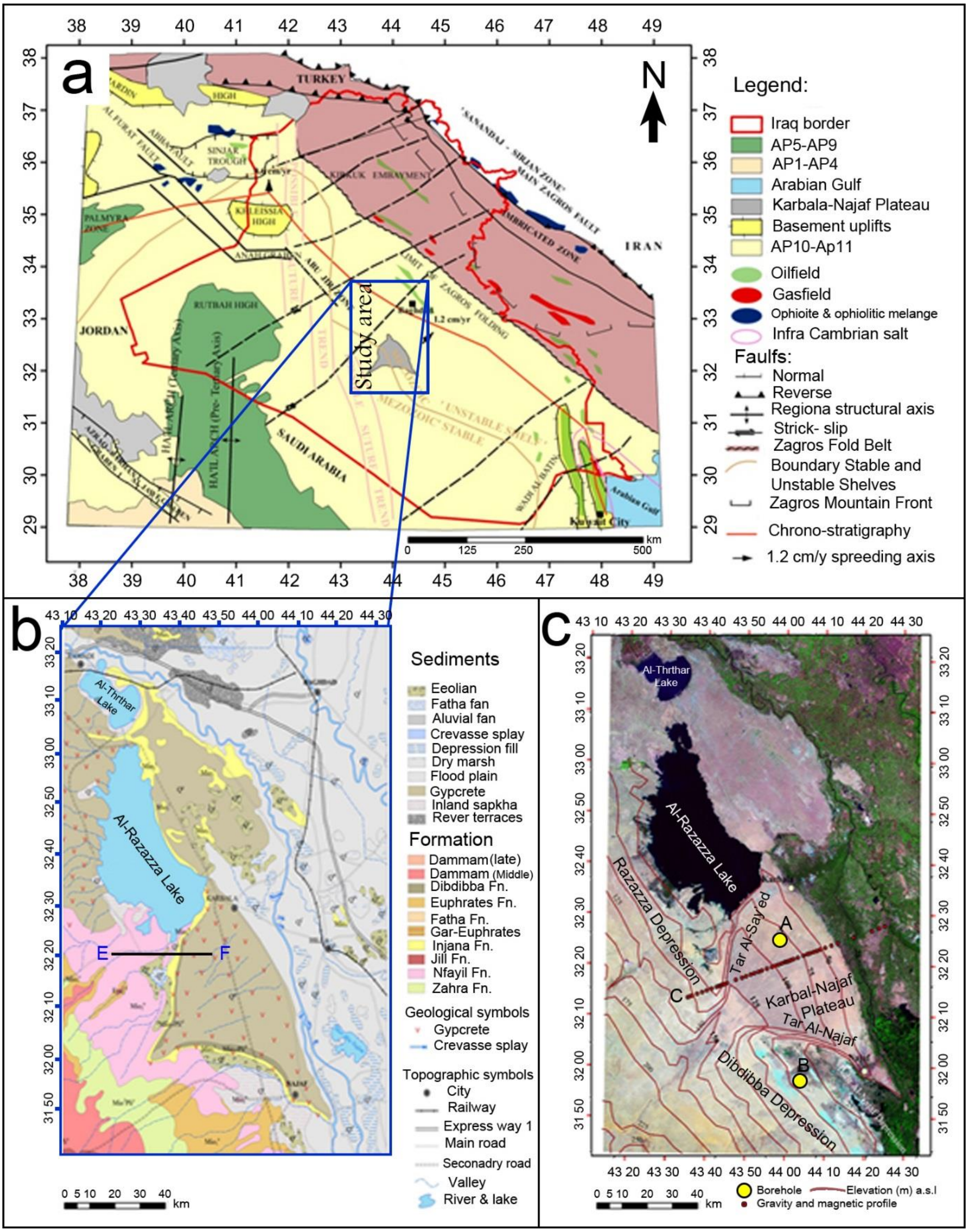

Fig.1: The study area; Karbala – Najaf Plateau (dark gray) within the tectonic elements of Iraq and surrounding areas **(a)**, (after Sharland *et al*., 2001); **b)** Geological map of the study area and surroundings; the Dibdibba and Injana formations appear as a fan shape (after Sissakian and Fouad, 2012); **c)** A satellite image shows the topography of the study area

A remarkable break in continuity of sedimentary beds is observed in the study area. The deformed brecciated unit of the Euphrates Formation is a syn-sedimentary deformational structure that indicates tectonic unrest during Early Miocene (Sissakian *et al*., 2014). Al-Razzazah Depression and Dibdibba Depression (Bahr Al-Najaf) are the two depressions affected the course of the River Euphrates (Sissakian *et al*., 2015). Al-Habbaniya, Al-Razzazah and Bahr Al-Najaf have same geological feature depressions developed as a response to the Abu Jir Fault activity (Abdul-Jabbar, 2013). This study aims to interpret the new tectonics of Abu Jir Fault during the last 5 M.Y based on mineralogical, geophysical and field evidence.

MATERIALS AND METHODS

The field work was conducted around the boundary between the Stable and Unstable Shelves including the Karbala-Najaf Plateau and Dibdibba Depression. The field work is focused on the stratigraphic setting, mineralogical variation and Gamma ray level in the study area. Exposures of geological formations have been followed in the field. It was observed that there is an abrupt interruption and discontinuity of layer extension. An east-west traverse, extending from the plateau to the Dibdibba Depression, normally across the fault direction determines the route of the present investigation. A total of fifteen sediment samples were collected along the traverse. These samples were subjected to the mineralogical identification. Samples were prepared in the Geochemistry Lab in the Department of Geology, College of Science, University of Baghdad. For the clastic sediments, very fine sand grains were obtained by standard sieving and chosen to make thin sections as scattered grains on glass. Mineralogical composition in percentage of each sample was estimated based on optical properties under transmitted polarized microscope. Point counter for 150 grains at least of very fine sand fraction were tested in each sample. To be sure that the quantity of gypsum in the recent sediments is accurate, loss on ignition (L.O.I) including SO_3 and H_2O was performed using a furnace at 600 °C for 2h. Radiometric survey was carried out along the traverse using the scintillometer (SSP-2-NF). The radiation level are measured and recorded in situ as average for three readings per each site. A scale f-150 of the scintillometer is selected to record the whole concentrations of radionuclides ^{238}U, ^{232}Th and ^{40}K. The gravity and magnetic data are in a standered Geosoft database format recovered by GEOSURV and GETECH (2011). These data are measured along a profile (C). Three derivatives; Total Horizontal Derivative (THD), Analytic Signal (AS) and Tilt Derivative (TDR) have been applied to clarify the effect of the fault in the area.

LITHOSTRATIGRAPHIC AND GEOMORPHOLOGICAL SETTING

The Karbala – Najaf Plateau rises gradually from the east towards the west and the lowest and highest points are 25 m and 150 m a.s.l. (Fig.1c). It is covered by Quaternary sediments composed mostly of gypcrete (Barwary and Slewa, 1994) (Fig.1b). The Euphrates, Nfayil, Injana and Dibdibba formations croping out in the study area are good evidence for interpreting the fault activity. In the middle of Iraq, the Euphrates Formation mainly consists of shallow marine carbonates represented by shelly, chalky, well bedded recrystallized limestone (Al-Dabbas *et al*., 2013 and 2014) with wide subsurface extension. The different lithological constituents of the formation, in different areas are due to the tectonic effect of Abu Jir Fault and the position within the depositional basin (Sissakian and Salman, 2007). The Nfayil Formation (M. Miocene) is equivalent to the Fatha Formation (I.P.C., 1963). It is widely exposed in the Stable Shelf at Rahaliyah, Shithatha, Qasir Al-Akhaidhir and Bahr Al-Najaf. Near Karbala, the lower member is 15 m thick and the upper member is 12 m, while near Al-Najaf, the lower member is 10 to 16 m, and the upper member is 20 to 25 m

(Al-Mubarak and Amin, 1983). The Injana Formation (Late Miocene – Pliocene) is wide spread throughout Iraq with absence in the Western Desert, southern Iraq (Basra), Saudi Arabia and Kuwait (Mukhopadhyay *et al*., 1995). It is composed of sandstone and siltstone alternation with claystone (Hassan, 2007). To the west of Karbala, a narrow strip of it is exposed along a cliff of Tar Al-Sayed. It also is exposed to along Tar Al-Najaf with 27 m thick which is reduced to 9 m towards the southeast (Dawood, 2000**)**. The Formation clearly extends at depth eastwards within the Unstable Shelf (I.P.C., 1963). It is overlain by the Dibdibba Formation which is a youngest in the stratigraphic column. The exposures of the Dibdibba Formation are restricted only at the Karbala-Najaf Plateau, Basra (Zubair – Safwan) and Saudi Arabian borders (Al-Sharbati and Ma'ala, 1983). The greater thickness is found in the south of Iraq and Kuwait, reaching 354 m in its type locality (Bellen *et al*., 1959); increasing to 500 m in wells of southern Iraq and the north Arabian Gulf (Jassim and Goff, 2006); but it decrease in the plateau to be 3 to 15.5 m. In southern Iraq, it is conformably underlain by the Fatha Formation (Bellen *et al*., 1959), but in Central Iraq is unconformably underlain by the Injana Formation (Hassan *et al*., 2002). In spite of the presence in Iraq, the Dibdibba Formation is also recognized in Kuwait. In Saudi Arabia similar facies are included (Hofuf Formation and partly in Kharj Formation) (Powers *et al*., 1966). The clastics of the Dibdibba Formation in southern Iraq, Kuwait, Saudi Arabia and Qatar (Hofuf Formation) were mainly supplied by the uplifted Stable Shelf (Mukhopadhyay *et al*., 1995).

RESULTS

- **Field Observation and Measurements**

The Karbala – Najaf plateau is of highest land extends more than 100 Km from north of Karbala to the south of Najaf. The western side (Tars) of the plateau is distinguished by sharp cliffs (Fig.2). The elevation of the plateau decreases gradually to the east, but westwards, the plateau has a sharp cliff which is locally named "Tars" (Tar Al-Sayyed at Karbala and Tar Al-Najaf at Al-Najaf). The cliff was developed in a steep escarpment due to the weathering agents. The stratigraphic succession has a sudden break on the west along Abu Jir Fault Zone, and the entire plateau disappears within the Stable Shelf where the older rocks start to expose on surface. The Dibdibba Formation forms the top of the Plateau covered by the Quaternary sediments with an approximate thickness ranging from 0.5 to 2.5 m. The Dibbdiba Formation is an important geological unit that can be used for the interpretation of new-tectonism in the Stable Shelf due to the sudden appearance of many formations of different ages occurring in the Razzazah and Dibdibba depressions. A new tectonic movements between the uplifted and subsided areas, in western Iraq was mentioned by Sissakian and Deikran (1998) and Sissakian and Deikran (2009) using remote sensing technique.

The thickness of the Dibdibba, Injana, Nfayil and Euphrates Formations are measured in borehole A and compered with their thickness in borehole B (Figs.1c and 3). In borehole A, the thickness of the Dibdibba Formation is 12 m; Injana 98 m, and Nfayil is 75 m. In borehole B, The Euphrates Formation is 38 m thick, while the a few meters for Nfayil. The relative variation in the depositional environment of the Euphrates Formation may be also attributed to simultaneous movement of blocks along the Abu Jir fault Zone with the deposition processes (Al-Dabbas *et al*., 2014). The upper contact of the Dammam Formation in borehole B was detected at 47 m depth which is equivalent to the sea level; while it was not detected in borehole A as it reaches deeper.

Fig.2: Sudden break in the western edge of the Karbala Plateau shows the high cliff (the eastern block) of Abu Jir fault line scrap

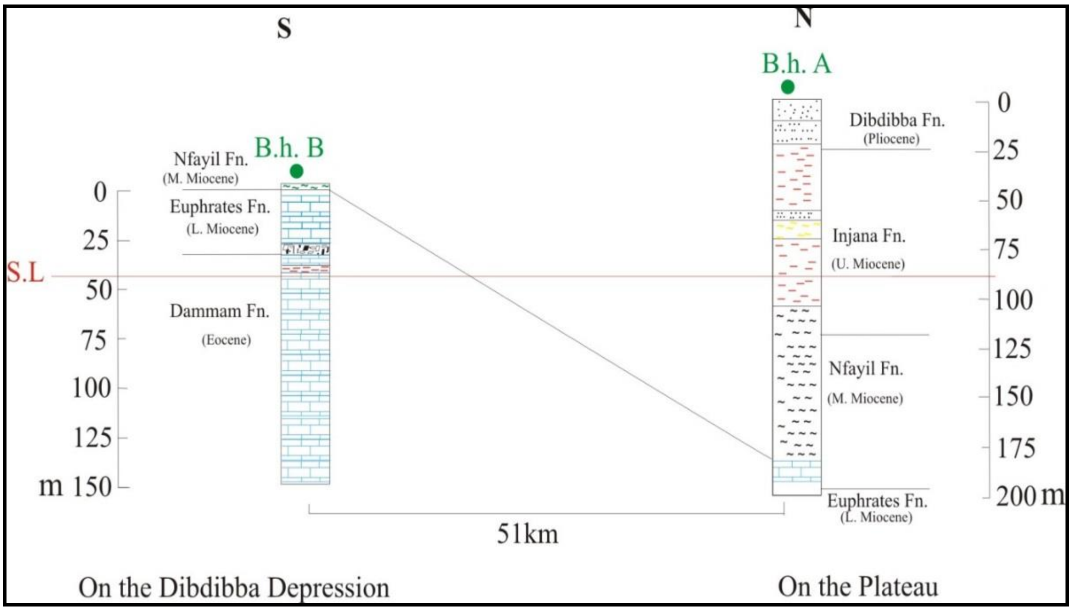

Fig.3: A correlation between boreholes A (on the plateau) and B (in the Stable Shelf. For location refer to Fig.1c)

- **Mineralogical and Gamma Radiation Evidence**

The sampling was carried out along a traverse (A – B) 40 Km long extending from the Karbala-Najaf Plateau in the east normally at the Abu-Jir Fault and up to the Razzazah Depression west (Fig.4). The traverse A – B has been fixed on the map in Fig.1c. The target of sampling is to identify the mineralogical and gamma ray variations in both sides of the fault. The Dibdibba Formation and its cover (recent sediments) was the target for the sampling process at the Karbala – Najaf Plateau which represents the eastern block; while the Nfayil Formation was a target for sampling on the western block.

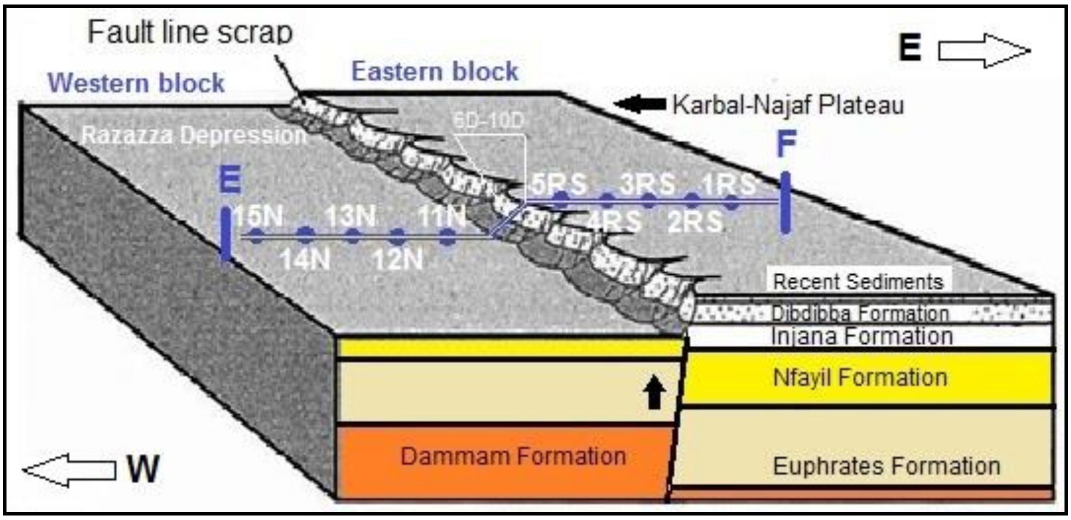

Fig.4: Sketch diagram shows the sampling traverse perpendicularly to the Fault, the traverse E – F is indicated in Fig.1c

The recent sediments covering the Karbala – Najaf plateau are unconsolidated sediments containing visible masses of friable gypsum. All gypsum are fibrous in texture belong to secondary gypsum that have been formed recently from the evaporite fluviatile environment on the Mesopotamian plain. The results of mineralogical composition and the gamma ray are listed in Table 1. The topography of the study area varies from 98 m on the plateau in the east to 52 m in the depression in the west (Fig.5). Consequently, a significant variation in the mineralogical composition and gamma ray on both sides of the fault has been recorded (Table 1 and Fig.5). The content of quartz, feldspar and gypsum in the plateau is greater than of that in the depression, whilst calcite and dolomite are found as an abundant components in the depression. In average, the quartz content in the recent sediment at plateau is 57.6%, while it increases to 88% in the Dibdibba Formation, then decreasing significantly (19.6%) in the Nfayil Formation at the depression. In the same manner, it can be seen that calcite, feldspar, dolomite and gypsum vary at the sudden break of the sedimentary sequences over Abu Jir Fault. The content of feldspar (20.2%), gypsum (9.4%) formed anomaly value in the plateau differs than of that in the depression (0.0 and 2.1%) respectively. Conversely, the calcite and dolomite showed clear variations on both sides of the fault characterized by an increase in the depression.

Gamma ray is another clear geochemical indication of where the block is faulted due to the variety of the radiation level on both sides of the fault (Table 1 and Fig.5). Gamma ray emitted from Karbala – Najaf Plateau is a total radiation coming from the Dibdibba formation and recent sediments, so, the average (c/s) radiation on the plateau along traverse samples 1RS-5RS is 33.3, and along traverse samples 6D-10D is 29.1, whilst suddenly increase in the depression to 40 c/s the Nfayil samples (11N to 15N).

Table 1: Microscopic data of mineralogical composition of each sample along traverse (shown in Figure) cross cuts Dibdibba (D) and Nfayil Formations (N) perpendicular to the Abu Jir Fault at Karbala plateau

S. No		Ele. (m)	Mineralogical composition (%)							Gamma Ray (Av)	
			Quartz	Calcite	Feldspar	Dolomite	Gypsum	C.M	RF	c/s F/150	c/s*3
1RS	Recent Sediments	88.0	62.0	17.0	5.0	3.0	13.3	3.5	2.0	11.0	33.0
2RS		89.0	64.0	25.0	3.0	1.0	3.30	3.5	3.0	12.0	36.0
3RS		92.0	48.0	29.0	2.0	4.0	15.7	7.0	1.0	11.0	33.0
4RS		93.0	54.0	24.0	1.0	3.0	15.1	2.0	2.0	11.0	33.0
5RS		97.0	60.0	19.0	4.0	2.0	13.6	5.0	1.0	10.5	31.5
Min		88.0	48.0	17.0	1.0	1.0	3.30	3.5	1.0	10.5	33.0
Max		97.0	64.0	29.0	5.0	4.0	15.7	7.0	3.0	12.0	36.0
Av.		92.0	57.6	22.5	3.0	2.6	9.4	4.2	1.8	11.1	33.3
6D	Dibdibba Formation	95.0	88.0	---	15	---	---	---	7	10.0	30.0
7D		94.5	72.0	---	22	---	---	---	6	10.0	30.0
8D		94.0	76.0	---	22	---	---	---	2	9.5	28.5
9D		93.5	77.0	---	20	---	---	---	3	9.0	27.0
10D		93.0	70.0	---	25	---	---	---	5	10.0	30.0
Min		93.0	70.0	---	15.0	---	---	---	2	9.0	27.0
Max		95.0	88.0	---	22.0	---	---	---	7	10.0	30.0
Av.			76.6	---	20.2	---	---	---	4.6	9.6	29.1
11N	Nfayil Formation	66.0	19.5	45.5	---	10.0	2.0	23.0	---	13.5	40.5
12N		52.0	25.0	50.0	---	6.0	---	19.0	---	12.5	37.5
13N		57.0	24.5	47.5	---	8.0	---	20.0	---	13.0	39.0
14N		55.0	16.0	39.5	---	15.0	3.5	26.0	---	14.5	43.5
15N		64.0	14.0	51.5	---	12.5	5.0	17.0	---	14.0	42.0
Min		52.0	14.0	39.5	---	6.0	2.0	19.0		12.5	37.5
Max		66.0	25.0	50.0	---	15.0	5.0	26.0		14.5	43.5
Av.			19.6	46.8	---	10.3	2.1	21.0	---	13.5	40.5

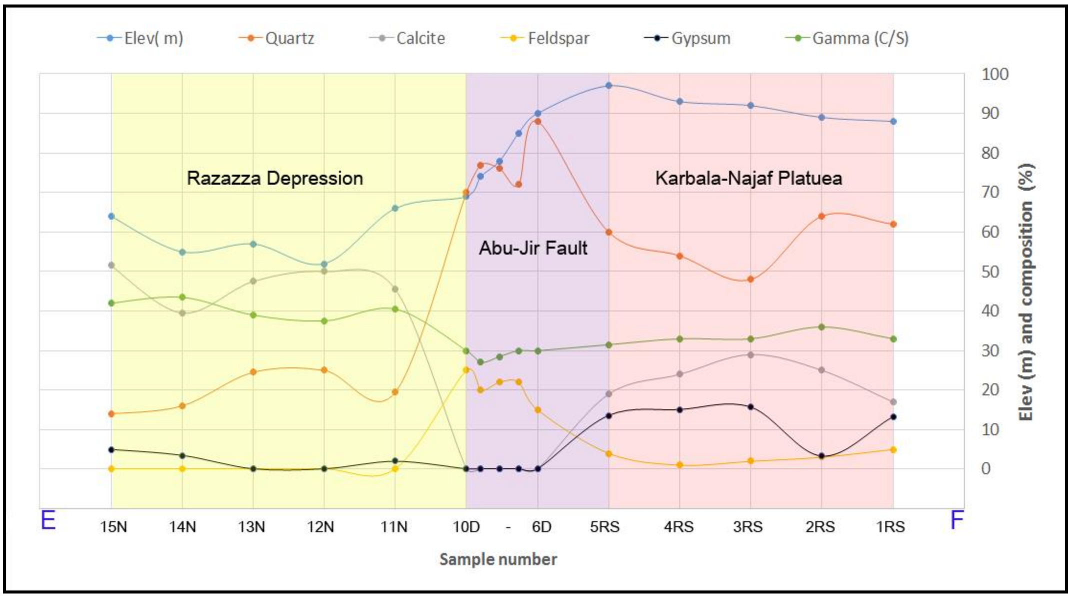

Fig.5: Variation of mineralogical composition and gamma ray perpendicularly to the fault along the sampling traverse E – F which is indicated in Fig.1b

- **Gravity and magnetic interpretation**

The residual gravity map of the study and surrounding areas is acquired by subtracting Bouguer map (Fig.6) from the 2000 m upward continuation map (supposed to be regional) (Fig.7). The 2000 m upward is chosen according to the interpretation results of power spectrum analysis (shown in the next paragraph). An elongated NW – SE positive anomaly with length of 27 Km and width of 16 Km with amplitude of up to +0.9 mGal underlain the central part of the Plateau. A negative anomaly of -1.0 mGal, which is the northwestern extension of the more regionalized negative anomaly lies at the southern edge of the plateau (Fig.6), bounds the positive anomaly with the same direction. The source of the positive anomaly could be explained as a relatively shallow positive structure (uplift) within the sedimentary cover. For the quantitative interpretation of this source, two slices are displayed from the power spectrum analysis of the Bouguer map (Fig.8). The first one is at depth of 12600 m, which is suggested to be related to the deep basement structures, while the second slice represents the depth of the source of the uplift which is 2880 m.

As mentioned before, the original aeromagnetic data of CGG (1974) has been reprocessed by GEOSURV and GETCH (2011) into a standard Geosoft database. These are used in this study where the (TMI) of the study area and surrounding has been transformed to the Reduction of the Pole map (RTP) as shown in Fig.9. The RTP map shows a NNW – SSE magnetic low of amplitude value close to -60 nT. Depth to Basement (DTB) has been calculated by applying the Source Parameter Imaging method (SPI), where the basement graben of NNW – SSE direction with an estimated depth of 8 – 9 Km is displayed as shown in Fig.10.

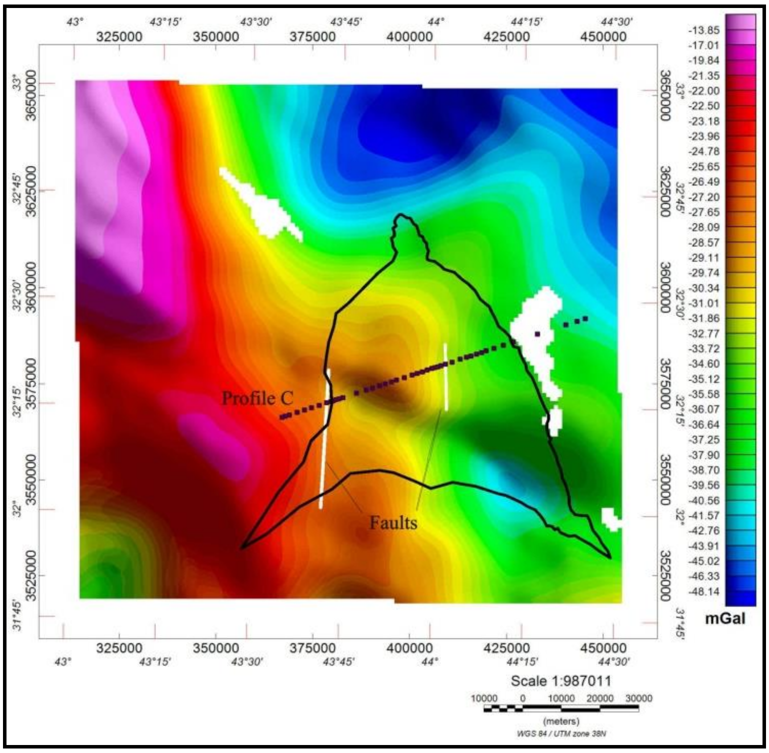

Fig.6: Bouguer anomaly map of the study area. The black color is the outline of Karbala – Najaf Plateau

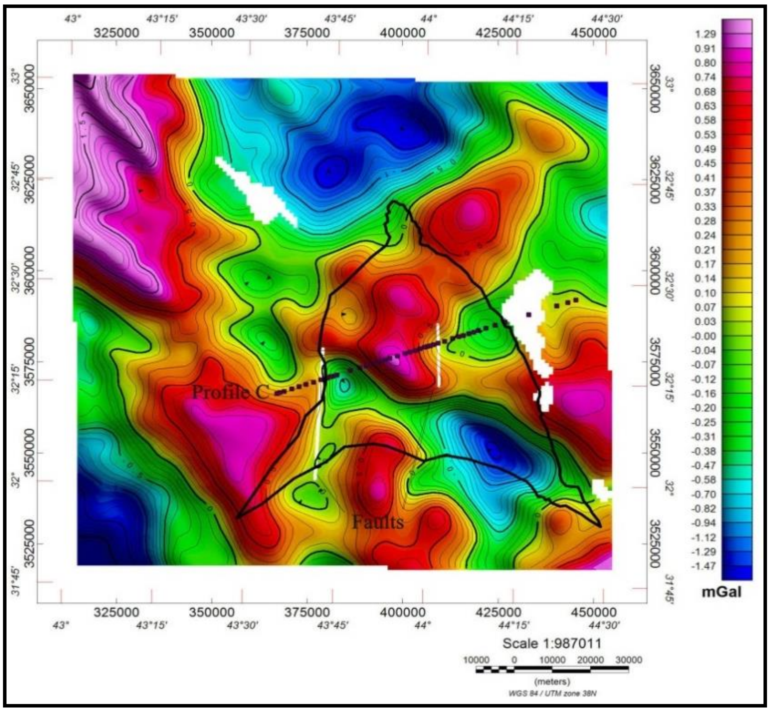

Fig.7: Residual gravity map, of the study area and surrounding, showing NW – SE trending positive gravity anomaly (+0.9 mGal) underlying Karbala – Najaf Plateau.
The black color is the outline of Karbala – Najaf Plateau

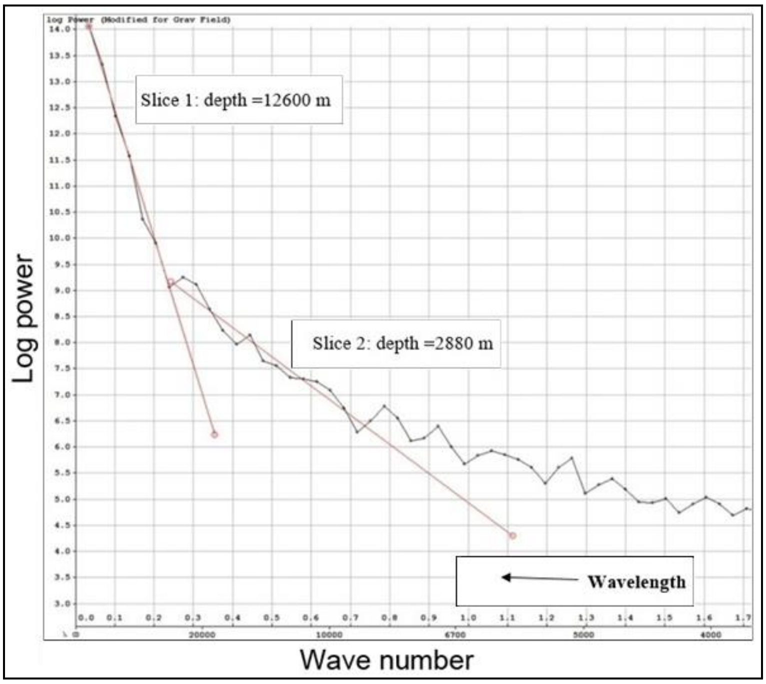

Fig.8: The power spectrum analysis of Bouguer anomalies in the study area

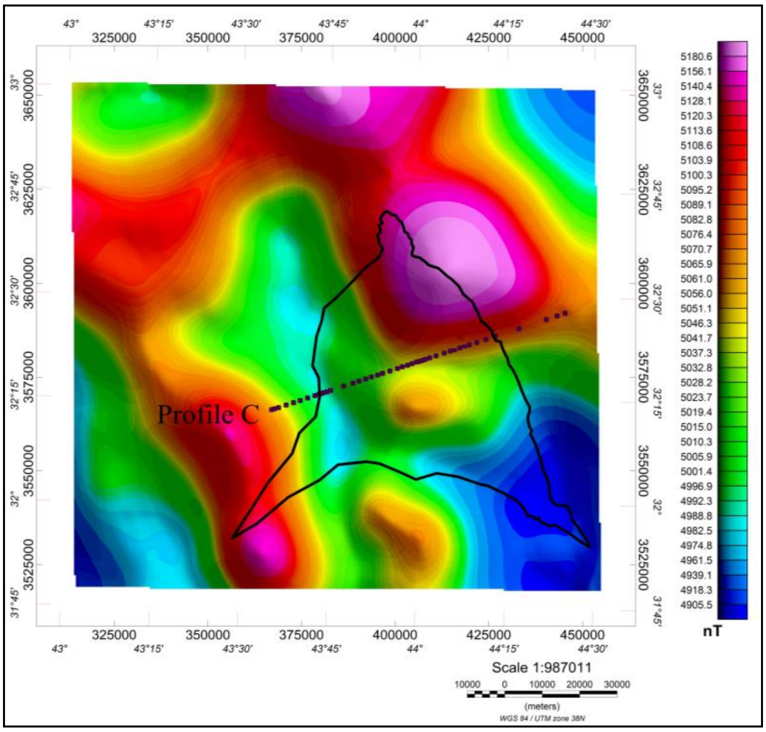

Fig.9: The RTP map of the study area and surrounding shows a NNW – SSE trending magnetic low underling Al-Habbaniya, Al-Razzazah and Bahr Al-Najaf depressions. The black color is the outline of Karbala – Najaf Plateau

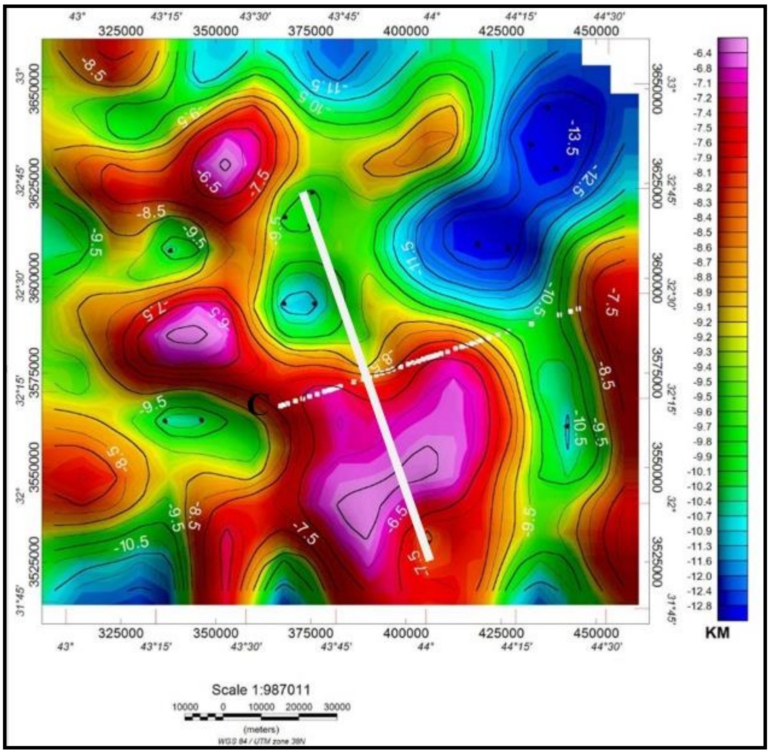

Fig.10: The DTB map using SPI method shows a basement graben of NNW – SSE direction; the solid white color line represents the axis of this graben

Three derivatives; Total Horizontal Derivative (THD), Analytic Signal (AS) and Tilt Derivative (TDR) have been applied to clarify the effect of the fault. The fault is determined wherever a zero value (zero crossing) in the TDR and two positive peaks in the AS and THD (Fairhead, 2004). For this purpose, the gravity and magnetic field along 83 Km length profile **(C)**, which is passing across the plateau, has been analysed and the three derivatives, are plotted against the distance (Figs.11 and 12).

The results show that two faults are determined along the profile C in the gravity maps (Figs.6 and 7) and one on the magnetic map in addition, the THD shows a high value or peak at a distance of 25 Km (Fig.11).

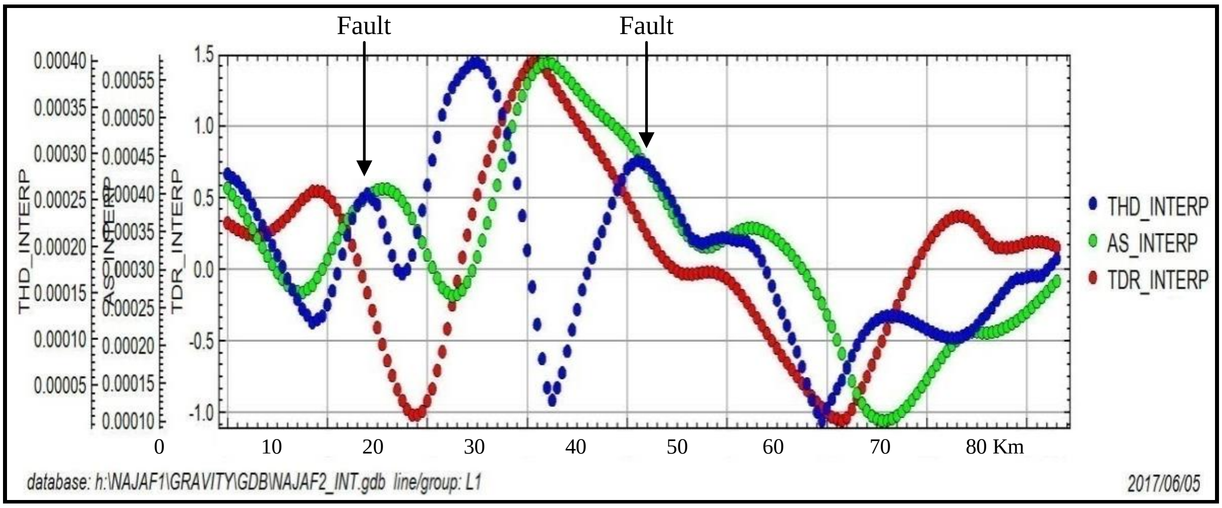

Fig.11: The THD, AS and TDR of Bouguer anomaly field along profile C. The two expected faults are shown (for location refer to Figs.1 and 3)

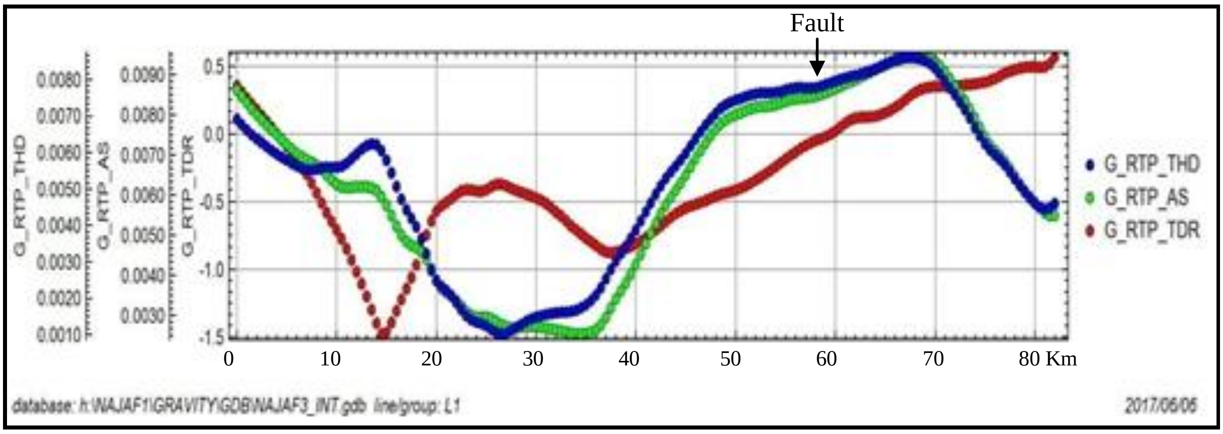

Fig.12: The THD, AS and TDR of the RTP field along profile C. One expected fault is shown (for location refer to Figs. 1 and 3)

DISCUSSION

The plateau was wider than its present shape; it was including the southern part of Al-Razzazah Lake and the northern part of Bar Al-Najaf Depression. As the plateau is positive area within a weakness zone represented by the NNW – SSE trending depression, the erosion is faster in the weakness areas i.e. the northern and southern parts of the plateau were eroded until the plateau has reached its fan-shaped at present. The determination of faults by the analysis of the gravity field may indicate that the process of evaluation of the structural high was associated with faulting. The eastern fault has reached the surface as reflected by two prominent features. The first one is the changing in the course of Euphrates River near Al-Musayab and assuming a straight line rather than the meandering (Fig.3), and the second is the linear shape of the eastern edge of the plateau. Dibdibba Formation has been deposited in a fluviatile sedimentary basin shared among Saudi, Kuwait and Iraq (Fig.13) from sediments that have been eroded of some parts of the Arabian Shield in the south-west (Awadh and Al-Ankaz, 2016). Geological principle of the original horizantality formulated by Nicolaus Steno, indicate that the sediments should be deposited horizontally composing horizontal layers; therefore it is more worth to find the Dibdibba Formation extended in the south part of the Western Desert within Salman zone and Rutba zone, reaching the Saudi Arabia, which is the source area.

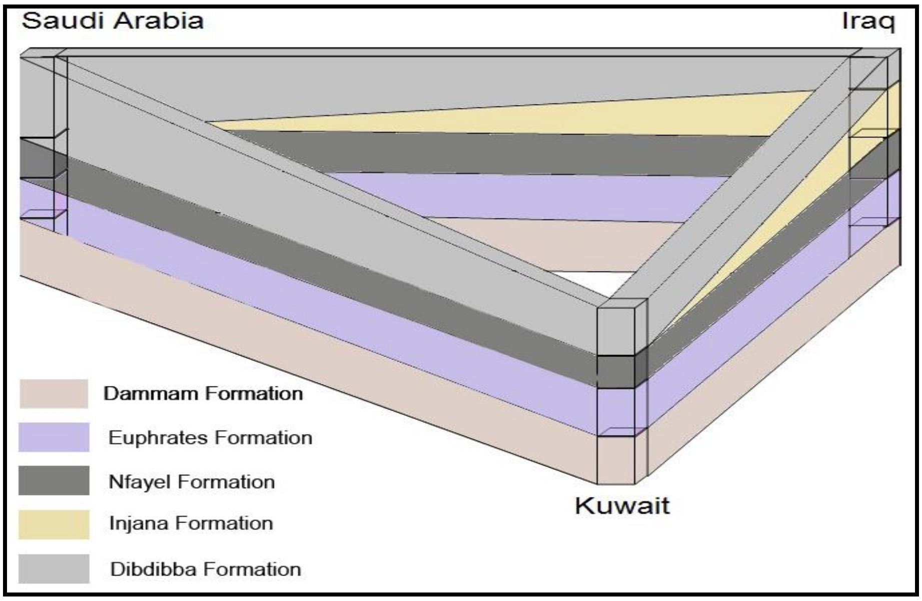

Fig.13: Sketch, fence diagram (not to scale) displays the depositional basin of Dibdibba Formation sharing among Saudi Arabia, Kuwait and Iraq

Figure 14A illustrates the horizontality principle at the preliminary stage. But the truth is the opposite, where the absence of Dibdibba Formation in the southern Desert of Iraq indicating eroded area (Fig.14C). The sharp interruption of the continuous formations (Dibdibba and Injana) abruptly is just evidence of Abu Jir Fault activity. This sudden interruption at the west block of the fault continues from Karbala to Basra, which confirms the movement of these blocks upward as a result of the stress of the Arabian Plate (Fig.14B). The ascended block is subjected to active erosion, so, it is has easily eroded (Awadh *et al*., 2013). The weathering and erosion agents have played their role at the elevated parts of Abu Jir Fault Zone and resulting flattened it again. Thereafter the western block became depressed and the eastern block stood as steep ridge known as Tar Al-Sayed and Tar Al-Najaf. The thickness of the sedimentary column of Dibdibba Formation is variable, the highest in Kuwait and Basra (354 m to 500 m), whilst the lowest is in Karbala (3 – 15 m) (Hassan *et al*., 2002). This conclusion is supported by the descent of the southern Basra block. The Dibdibba Formation reveals that the Karbala – Najaf Plateau was low land during deposition span which appears as high land now. The bottom of Dibdibba Formation at Basra is below the sea level, where it is above the sea level at Karbala (81 m) (Awadh and Al-Ankaz, 2016). The field observation reveals that the carbonate facies of the Nfayil Formation in the southern west of Iraq passed into gypsum facies of the Fatha Formation in the north and northwest of Iraq along Abu Jir Fault Zone. This was due to the dynamic of fault, thus confirming the rise of the western block relative to the eastern block. Since the western block placed within the Stable Shelf, it has been subjected to an uplift during deposition of the Nfayil Formation. This is a convincing evidence confirming that the Stable Shelf has been uplifted.

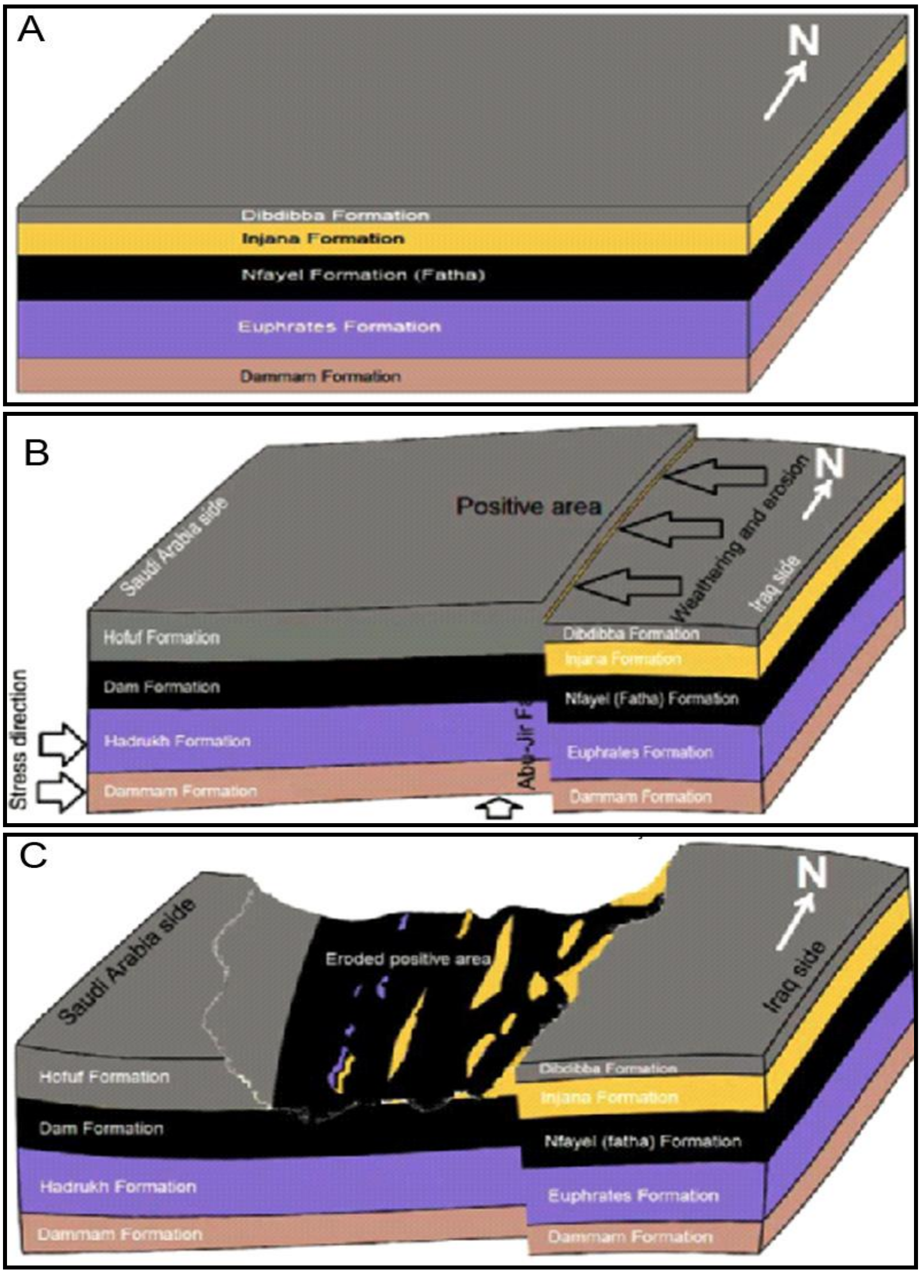

Fig.14: Block diagram illustrates the sedimentary basin developed post deposition of the Dibdibba Formation (Pliocene – Pleistocene) along Abu Jir Fault Zone;
A) Horizontality principle at the preliminary stage of Dibdibba Formation deposition;
B) Movement of the western block upthrown as response to the stress of the Arabian Plate movement; **C)** Removal large masses of sediments due to eroded the highland of the upthrown block

CONCLUSIONS

- The clasts of Dibdibba Formation are well developed in different parts of the neighboring territories, such as the Al-Hufuf Formations in the Saudi Arabia, but in Kuwait still the same names in use.
- Quaternary sediments unconformably overlie Dibdibba Formation. The clastic sediments of Dibdibba Formation are exposed on the eastern block of the Abu Jir Fault in the study area underlying a thin gypsiferous soil of Quaternary age.
- The Al-Najaf Plateau has an elongated NW – SE trending positive gravity anomaly of amplitude +0.9 mGal indicates a NW – SE trending structural high of estimated depth 3 Km formed probably simultaneously with faulting.
- The sedimentary succession in the study area is affected by two faults demonstrated by applying the THD, TDR and AS derivatives of the gravity field analysis.
- The Dibdibba Formation shows a good evidence for interpreting the post depositional tectonic origin (new tectonic after Pliocene – Pleistocene) of the Stable Shelf in Iraq. The discontinuity and the sudden termination of Injana and Dibdibba Formations along the Abu Jir Fault forming a high standing cliff with elevation of about 97 m on the eastern fault block on the Karbala Plateau, and more than 100 m at Najaf provides convincing evidence of the activity of the Abu Jir Fault after the deposition of Dibdibba Formation.
- The stratigraphic succession indicates that the western block of Abu Jir Fault has been uplifted forming a high land zone subjected to the erosion. The monocline gentle dip of the eastern fault block support this conclusion. Thereafter, the highland of the Dibdibba and Injana Formations were eroded. This is why they disappeared from the western block of Abu Jir Fault.
- The existence of Dibdibba Formation in SE of the Saudi Arabia (which is a source area) and disappear in western and southern Iraq except Basra, enhance that the erosion process followed uplifting was a control factor forming the Tar Al-Sayed and Tar Al-Najaf as a geomorpgological – tectonoic origin.
- The fault displacement resulted in a pronounced topographic evidence in the study area. The upthrown block (western block) was eroded to the lower level of the downthrown (eastern block) forming many depressions.
- The present shape of The Karbala – Najaf Plateau is related to the tectonic-erosional action, and not related to the depositional processes as it has been believed before.

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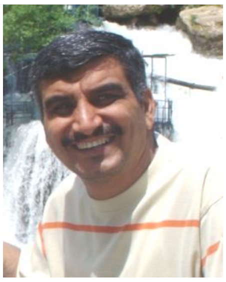

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