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Effect of Fractures on Euphrates River in Mesopotamian Basin in Iraq

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ABSTRACT

The study area lies in the middle of Iraq in Mesopotamian Basin between Karbala and Najaf provinces in area called Tar Al-Say'ed and Tar Al-Najaf, they are two conspicuous geomorphological outstanding features with an area 15022.4 km². The aim of this study is finding the relationship between fractures analysis and Euphrates River Basin. A comprehensive analysis of fracture traces is discussed in this study. The analysis covers various topics such as fracture trace, rose diagrams, rose maps, stress – strain, and lineaments; the rose diagram for the study area shows the dominated direction trend is E - W and second trend is NW- SE (315) and N-S trend reflect the effect of Najd and Euphrates faults in the study area. More than one hundred stations in Karbala (Tar-iAl-Say'edand Tar Al-Najaf) were taken in order to draw the poles in the study area. Fractures were divided into extension sets and shear systems. Shear fractures could have developed under a stress regime when the maximum principal stress axis was approximately NW-SEi (Horizontal) the intermediate principal stress axis (vertical) represents the old fractures in the area while the two systems of fractures (1) and (2) with (4) sets is directions are extension fractures with nearly horizontal beds in the stable shelf (west of Euphrates River) represent young fractures.

KEYWORDS: *Fractures; Mesopotamia Basin; Lineaments; Shear fractures; Extension fractures.*

INTRODUCTION

Brittle structures such as joints, veins, fissures, and faults are found almost everywhere at the surface of the solid Earth. Brittle structures can form rather gently in rocks undergoing exhumation and cooling or more violently during earthquakes. Fractures analysis is a powerful tool for use in analyzing stress conditions during tectonic activity also useful to know fracture patterns from an economic point of view (Fossen, 2013).

In Euphrates River Basin there has not been much research work entirely devoted to the relationship between fractures, but one of (Al-Sakini,1995) conclusions is that the major fault or joint sets of the Euphrates valley are tend to be parallel with and normal to the major structural fractures.

Few studies were achieved in the study area mention them; (Al- Shammari, 2013) studied Rock Slope Stability Assessment for Selected Sites From Tar Al – Najaf Area and concluded that a landslide hazard map for the study area is constructed at a scale (1:12500), for the first time depending on ten factors according to landslide possibility index system (LPI) to assess the hazards of (57) sites in the area. Hazards in the area are classified into three categories (no hazard, low hazard, and moderate hazard).

Sissakian, et al, (2013). "They studied Origin of Tar Al-Say'ed and Tar Al-Najaf, Karbala-Najaf, and concluded the top surface between the two cliffs (tars) 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. Consequently, the depression was divided into two parts, to the left is called Al-Razzazah Depression, whereas to the right is called Bahr Al-Najaf. This affected the course of the Euphrates River. This alluvial fan was deposited during Pleistocene, during the late Pleistocene and/or early Holocene, a neotectonic activity caused the rising of the involved area of the alluvial fan and nearby surroundings. This is attributed to the active Abu Jir-Euphrates Tectonic Zone, which is still an active zone".

Abdul-Khaleq, (2013). "Study tectonic of Al-Thirthar, Al-Habbaniya, and Al-Razzazah Depressions in the middle of Iraq, he had concluded there are three groups of lineaments. The first group is trending east-west perpendicular to the extensional structures beneath the three depressions. The second group is trending N60°E-S60°W perpendicular to the most of the normal faults in the extensional zone. The third group is trending N30°W parallel to the most of the normal faults in Extensional Zone. The extension structures are called Lake Fault system. It is an arcuate fault system convex westward. It extends from north of Al-Thirthar Lake to the south of Al-Razzazah Lake". It comprises grabens, horsts and normal faults. The Lake Fault System is formed during Late Triassic.

Abdulateef, (2017). Studied Hydrocarbon Seepages in KIFL oil Field Central IRAQ Using Satellite Imagery and Geological Data he used the remote sensing techniques such as Supervised Classification (SC), Normalized Difference Vegetation Index (NDVI), Ferrous Carbonate (ΔC), Clay Mineral Alteration (CMA), Thermal Analysis (THA), Topographic Analysis (TA), and Lineaments Analysis (LA), as well as analysis of geophysical data such as gravity data and seismic data by integration evidences of hydrocarbon, it is illustrated two regions of optimal hydrocarbon prospective in the study area which may be promising for exploration and production of oil and gas.

The aim of this study is to make fractures analysis and the relationship between the Euphrates River and these fractures. Faulting makes an important contribution to the total deformation at Euphrates River basin and several sets of faults have been identified.

Location of Study Area

The study area lies within the middle of Iraq in Mesopotamian Basin between Karbala and Najaf provinces in area called Tar Al-Say'ed and Tar Al-Najaf they are two distinguished geomorphological prominent features with an area 15022.4ikm^2,,the geographic coordinates s:
(43º 18` E- 32º 48` N), (44º 19` E- 33º 7` N), (44º 57` E- 31º 52` N), (44º 13` E- 31º 26` N). As in figure (1).

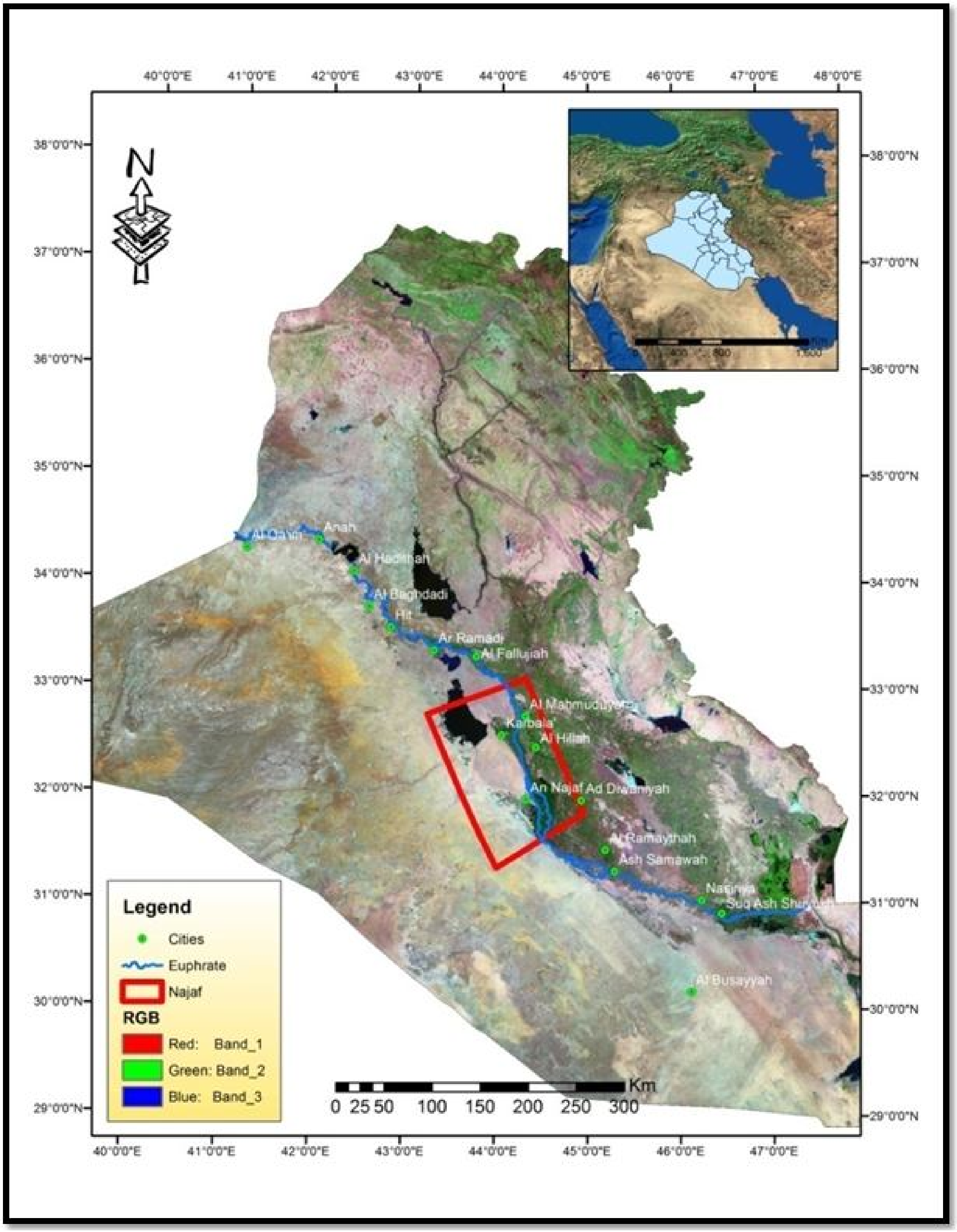

Figure 1: Area of study region

MATERIALS AND METHODS

Materials utilized in the study

To accomplish the current study, the accompanying materials were utilized:

1. Satellite image of Landsat 8 OLI (Operation Land Imager) (band 6) was used to study lineament in the area of study region.
2. High resolution images (quick birds) with 0.6 m as well as Google Earth images to distinguished urban, vegetation, and offices closed to the River Basin.
3. Topographical Maps: a number of topographic maps of scale 1:100000 aggregated by catalog of military study so as to know the street, towns, and different highlights.
4. Relevant articles, reports, and postulation related with the area of study region.
5. And Field observations and measurement data provide us information about geometrical characteristics of the structural and tectonics activities. Field work was conducted to obtain data on the characteristics of brittle deformation features (i.e., fractures).

Software used in the study.

The utilized software's are listed below:

1. PCI Geomatica V. 2013 software was used for lineaments extraction.
2. Arc GIS V.10 the GIS software was used, since there was an enormous number of information from different sources (Thematic guides, satellite pictures … and so on.); in various forms (raster, vector), and in various guides projections as well as maps layout.
3. Rock ware V.15 software was used in directional analysis for lineament such as frequency and length rose diagram.
4. Stereonet Windows V 9: Software was used for calculate and analysis of field data and plotting Planer features (e.g., poles).

Tectonic History of Iraq

The tectonic history of Iraq is identified with the plate tectonics developments in the Middle East district. Broadly, it includes the development of the Arabian, Eurasian, Iranian, and Turkish plates. "The Arabian plate is surrounded by active tectonic margins; the northern and eastern margins of the plate are composed of the compression regimes of the Taurus suture zone to the north and Zagros thrust zone in the east. Three major fault systems were available in Iraq N-S Nabitah (Idsas) System, the NW-SE Najd System, and the NE-SW or E-W Transversal System. These fault systems formed during the late Precambrian Nabitah orogeny. They were re-activated repeatedly during the Phanerozoic" (Jassim and Goff, 2006) as shown in figure (2).

Euphrates River was influenced by Najd faults system (from fig 2). Particularly the Euphrates Boundary Fault Zone is one of the most noticeable Najd faults reaches. It runs along the Euphrates River in S Iraq and proceeds towards theiRutba territory in W Iraq. In the S the fault zone include a sets of faults sometimes associated with grabens, and forms the boundary between the Quaternary Mesopotamian Plain and the rocky desert of SW Iraq. Lineaments were delineated in the study area using PCI Geomatica software as shown in figure (3).

Table 1: Basic statistics for lineaments

Statistics	Direction				
	N-S	NE-SW	E-W	NW-SE	All Directions
Count	406	421	391	501	1719
Min.length.	1.1	1.1	1.1	1.1	1.1
Max.length.	24.4	28.1	28.1	28.1	28.1
Mean.	2.6	2.8	2.7	2.8	2.7
Total length.	1065	1212	1071	1412	4762

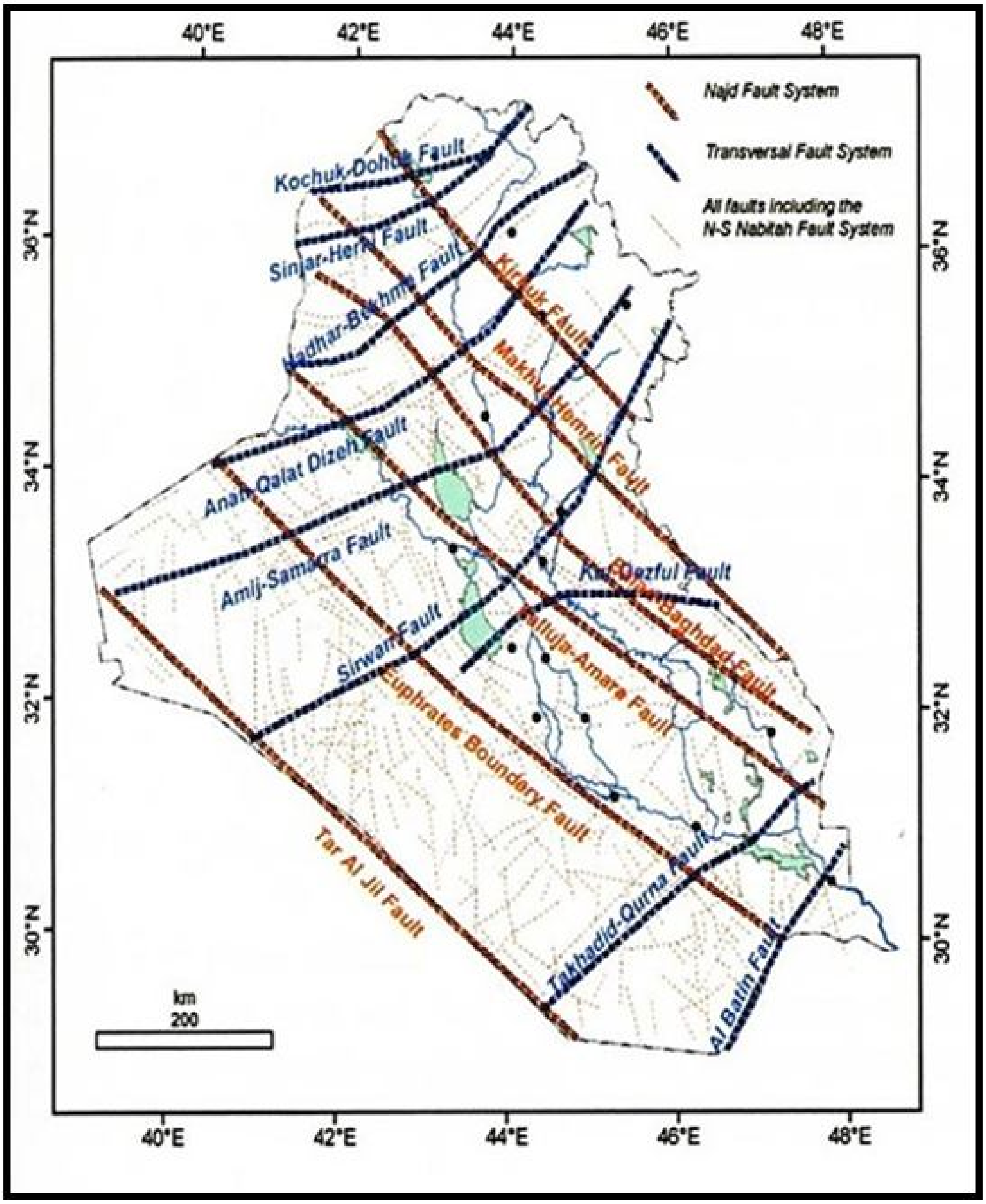

Figure 2: Faults allocation in Iraqi (after Jassim & Goff, 2006)

Geometric data of faults were collected to dentify the orientation of these faults and correlated them with the tectonic events n the study area (Ghareb, et al. 2019).

Rose diagram was achieved to study area in order to know the dominate tectonic forces affected the area. As shown in figure (4).

The rose diagram for area of study region shows the dominated direction trend is Ei-W and second trend is NW- SEi (315) and N-S trend.

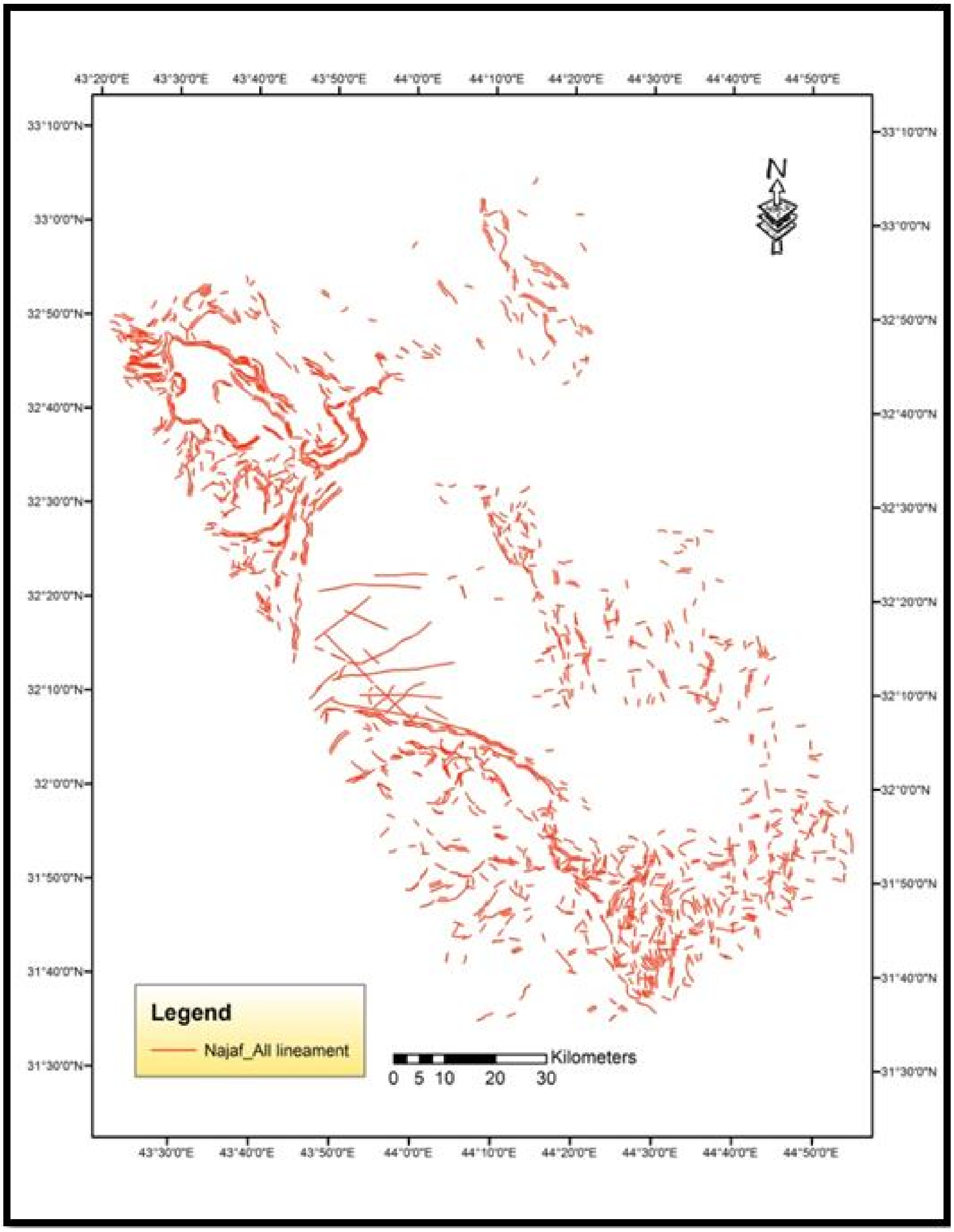

Figure 3: Lineament in study area and the statistics of these lineaments as in table (1).

Geology of the study region

The study area contained many formations are listed from oldest to youngest (Al-Khateeb & Hassan, 2005).

Dammam Formation (Middle Eocene).

The Dammam Formation comprises limestone (chalky, dolomatic) it was divided into five informal members. In the supplementary type section in Zubair well 3 of the Mesopotamian zone. The age of Dammam Formation in the supplementary subsurface type section in Iraq Middle Eocene (Bellen et al, 1959).

Injana Formation (Upper Miocene)

The Injana Formation comprises fine grained pre-molasse sediments deposited nitially n coastal areas, and later n a fluvio lacustrine system.The formation consists of red, partly greenish silty, sandy calcareous claystone and lenticels of grey, brownish, greenish and yellowish sandstone.The formation s exposed along ridges of Tar Al-Najaf (Jassim et al., 1984).

Dibdiba Formation (Pliocene-Pleistocene)

The Dibdibba Formation contains permeable sandstones (partly pebbly) with beds of mudstone, siltstone, and marl associated with secondary gypsum. The sandstones are probably hydraulically connected due to lateral pinch out of the mpermeable layers. Other rock types are silty claystone-clayey siltstone. The top of the formation s covered unconformably everywhere by gypcrete followed by eolian sands and silts.

Quaternary Deposits (Pleistocene- Holocen)

Different types of Quaternary sediments are developed n the studied area; they are the deposits which referred to the quaternary age. These deposits cover most parts of the study area and nclude many deposits such as (flood plian deposits, Aeolian deposits, nland sabkha and Gypcrete deposits). As shown in figure (5).

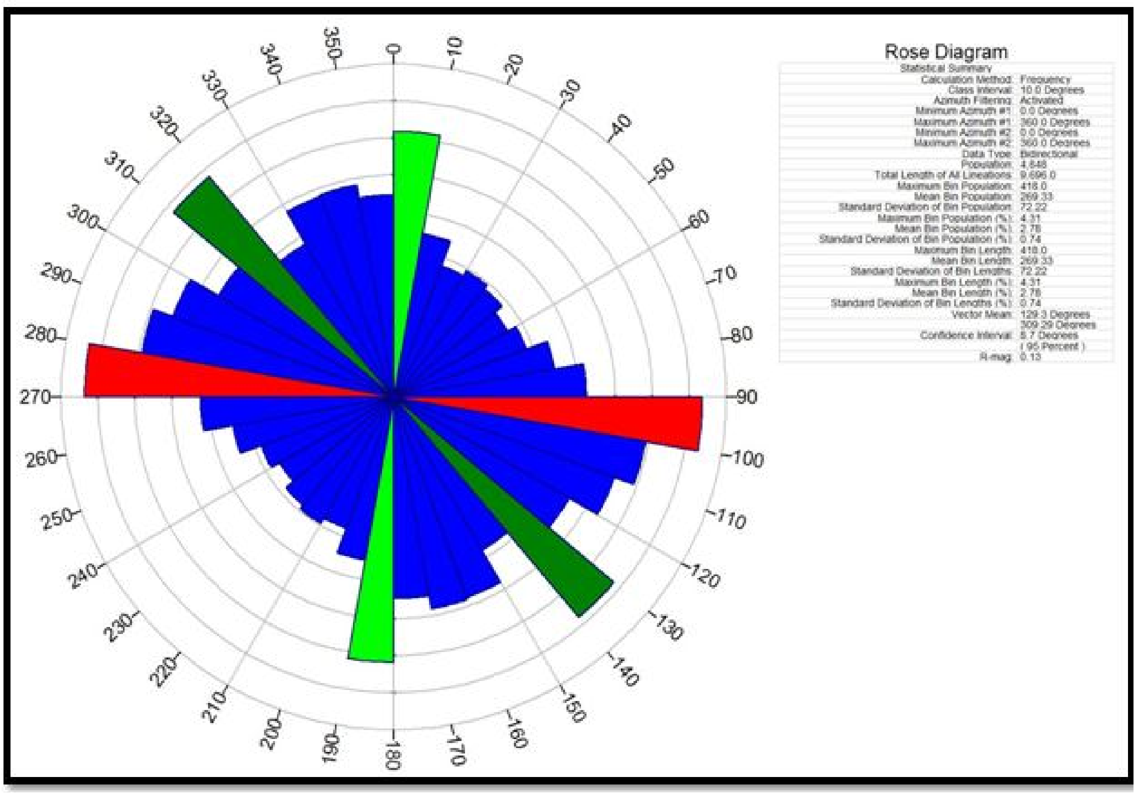

Figure 4: Rose diagram lineaments for Area of study region

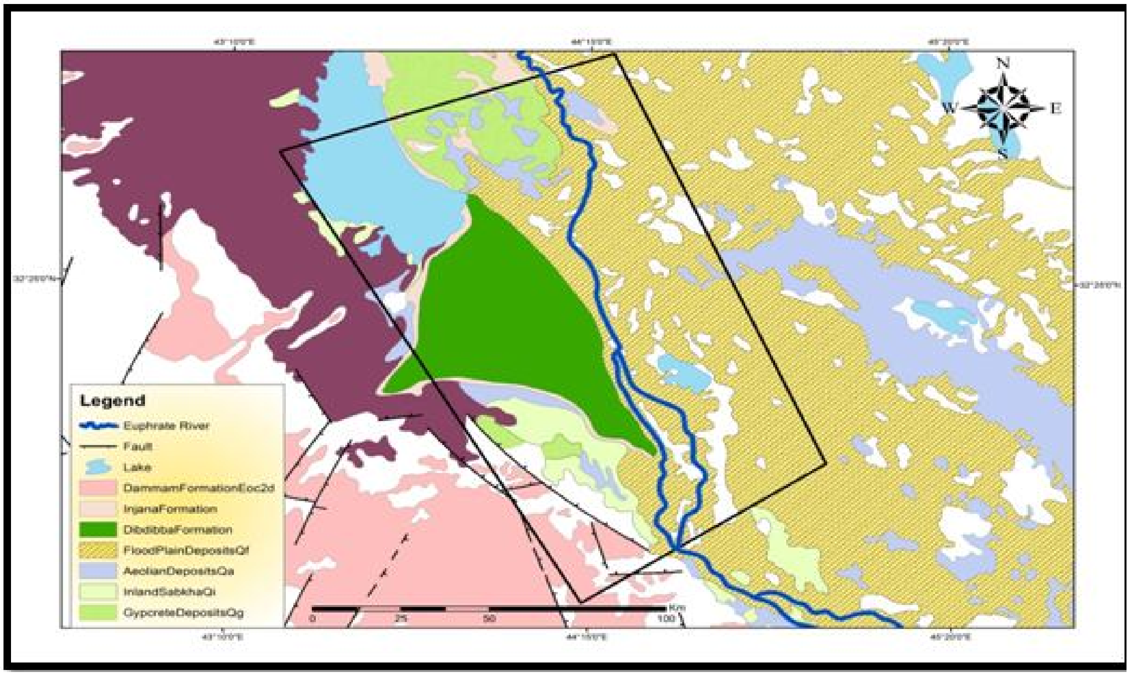

Figure 5: Digital geological map modified after (Sissakian, and Deikran, 1998)

RESULTS

From this research; the accompanying outcomes can be accomplished:

Stress form fault in the study area

According to (Fossin, 2013), "fault observation used in paleostress analysis includes the local Strike and Dip of fault surface, the orientation of lineation and the sense of movement. Faults from the study area can be analyzed to reconstruct the paleostress field of Euphrates River Basin".

According to (Anderson, 1942), "the maximum principal stress axis bisects the acute angle of conjugate faults. Depending on our data of Euphrates River Basin shows that this area is affected by several movements from Paleozoic to Cenozoic age".

The assumption of conjugate shear fractures along the Euphrates River Basin reveal the orientation of the principal stresses. This arrangement is referred to as orthorhombic based on its symmetry elements. As shown in figure (6). This represents the hypothetical Euphrates River course from Anah province, Ramadi, Baghdad, Najaf, Nassiyria, and Basrah province (including the study area in Al-Najaf area).

According to (Wallace, 1952), in the study area, "fault patterns show evidence of repeated activation under changing stress conditions. It seems reasonable to make the assumption that slip on the surface occurred in the direction of maximum resolved shear stress. If the largest shear stress is in the direction, we will get normal faults (Quaternary faults). If the maximum shear stress vector is horizontal, Strike-slip faulting results (Pre-cambrian faults)".

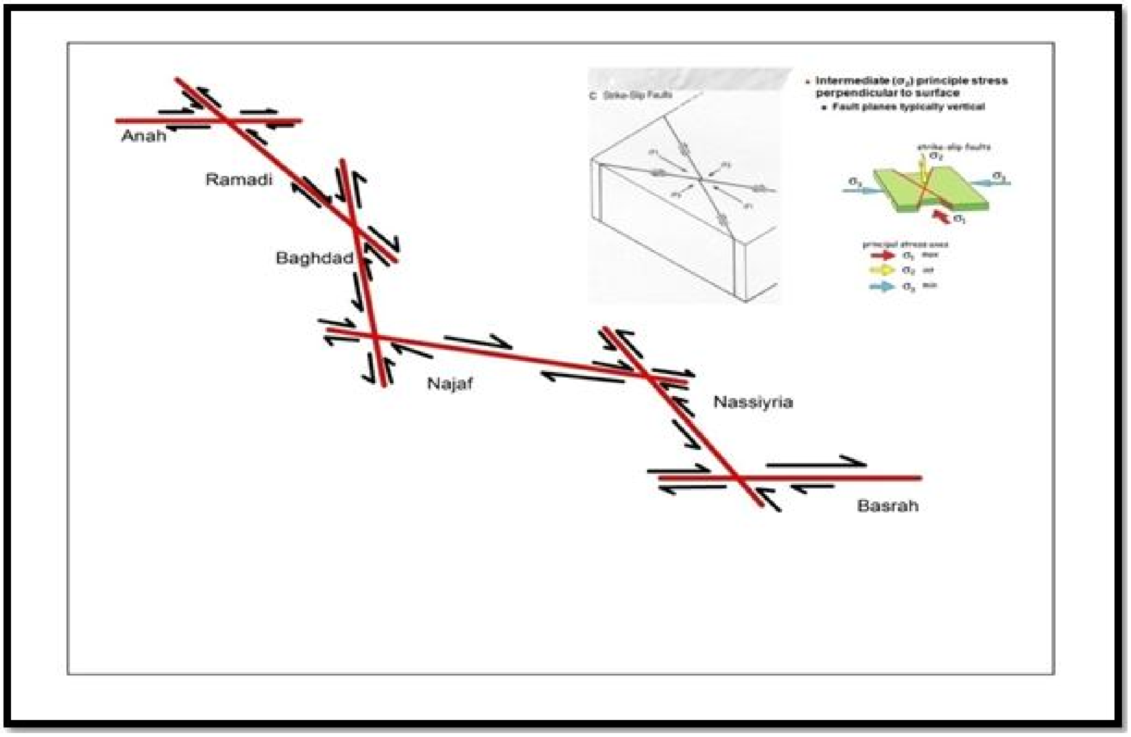

Figure 6: shows conjugate fracture along Euphrates River Basin

Fracture observations in the study area.

The presence of fractures for area of study region in territory Karbala and Najaf,which is called Tar Al-Say'ed and Tar Al-Najaf they are two conspicuous geomorphological outstanding features as shown in figure (1). "Tar" is a local name for a cliff. Tar Al-Say'ed (The length of the cliff is 105.1 km, maximum height difference along the cliff is 21.7im, its direction is NE-SW with clear circular inclination towards NNE in its extreme part, near Karbala city) and Tar Al-Najf (The length of the cliff is 103.4 km, maximum height difference along the cliff is 21.5 m, and its direction is NW-SE, with clear circular inclination towards SSE in its extreme part, near Najaf city) form elongated and steep cliffs, meeting at appoint called "Al-Lisan" area, which forms the head of a triangle formed by the two cliffs, whereas the base of the triangle is a flat area, forming the boundary between the flat Mesopotamia Plain and gently sloping plain of the Karbala-Najaf Alluvial Fan". (Sissakian, et al, 2013).

Fracture Analysis in the study area

A comprehensive analysis of fracture traces is discussed in this study. The analysis covers various topics such as fracture trace, rose diagrams, rose maps, stress – strain, and lineaments. In the end a structural conclusion concerning the tectonic development of the area is formulated. The occurrence of fracturing is often ascribed to the tectonic forces acting on the rock mass. However, many shear fractures (faults) have been observed in the rock formations (west of Euphrates River) which show no apparent signs of deformations. Most fractures in the area are vertical or nearly vertical in attitude. As shown in figure (7).

Figure 7: Sandstone rocks in study area Injana formation shows fractures attitude measured (dip and strike)

One hundred stations in Karbala (Tar-iAl-Say'ediand Tar Al-Najaf) were taken in order to draw the poles in the study area. As shown in table (2).

Table 2: Structure reading of fractures from the field

No	Strike	Dip Amount	Dip Direction	No	Strike	Dip Amount	Dip Direction	No	Strike	Dip Amount	Dip Direction
1	295	88	N	35	211	85	W	69	237	87	N
2	315	87	N	36	130	88	S	70	211	86	W
3	284	88	N	37	230	88	N	71	223	86	W
4	320	88	E	38	220	88	W	72	134	88	S
5	320	87	E	39	48	88	S	73	290	88	N
6	302	88	N	40	290	88	N	74	326	89	E
7	324	87	E	41	212	85	W	75	328	88	E
8	330	85	E	42	320	86	E	76	312	87	N
9	222	88	W	43	224	86	W	77	297	87	N
10	300	88	N	44	200	85	W	78	301	88	N
11	280	88	N	45	284	88	N	79	334	86	E
12	300	87	N	46	319	96	E	80	129	89	S
13	240	75	N	47	295	88	N	81	292	87	N
14	140	84	W	48	304	84	N	82	296	87	N
15	306	86	N	49	44	87	E	83	57	88	S
16	222	88	W	50	45	87	E	84	35	88	E
17	210	78	W	51	129	88	S	85	30	87	E
18	215	88	W	52	336	87	E	86	33	87	E
19	308	87	N	53	284	88	N	87	36	86	E
20	300	89	N	54	285	86	N	88	25	88	E
21	230	88	N	55	289	89	N	89	37	89	E
22	292	82	N	56	55	87	S	90	55	88	S
23	52	85	S	57	69	86	S	91	44	86	E
24	60	89	S	58	70	88	S	92	46	88	S
25	224	88	W	59	148	86	W	93	36	87	E
26	30	82	E	60	150	88	W	94	142	88	W
27	138	88	W	61	133	88	S	95	117	87	S
28	22	82	E	62	104	88	S	96	122	86	S
29	43	87	E	63	105	87	S	97	124	87	S
30	132	82	S	64	109	87	E	98	135	86	S
31	336	89	E	65	109	86	S	99	130	85	S
32	216	84	W	66	147	88	W	100	131	86	S
33	220	88	W	67	228	87	N				
34	300	85	N	68	234	88	N				

However, their strike directions showed diverse variations. On geometrical basis, they are grouped into four main sets. These sets from two systems-

System (1)
Fracture set (1) and (2) constitute these orthogonal systems which are present at all stations.

- Fracture Sets (1): Vertical or nearly vertical joints striking N40W from set (1). The amount of dip at this area is an excess of 4. The line intersection of fracture set (1) with the layering is parallel to its strike direction.
- Fracture Sets (2): The main trend of the strike of surfaces belonging to set (2) is N45E and their amount dip is approximately 90. The line of intersection between the sets 2 and the layering is parallel to the dip direction of the layering.

System (2)

- Fracture Sets (3): Nearly vertical fractures striking N60W.
- Fracture Sets (4): Vertical joints striking N30E.

We conclude that these systems (1) and (2) are extension fractures.
Two systems of fractures each comprising two orthogonal sets are associated with nearly horizontal beds in the stable shelf (west of Euphrates River). The general strike directions of the two sets of one system are NW-SE, while the general strike directions of the two sets of the second system are NE-SW and E-W (Figure 8).

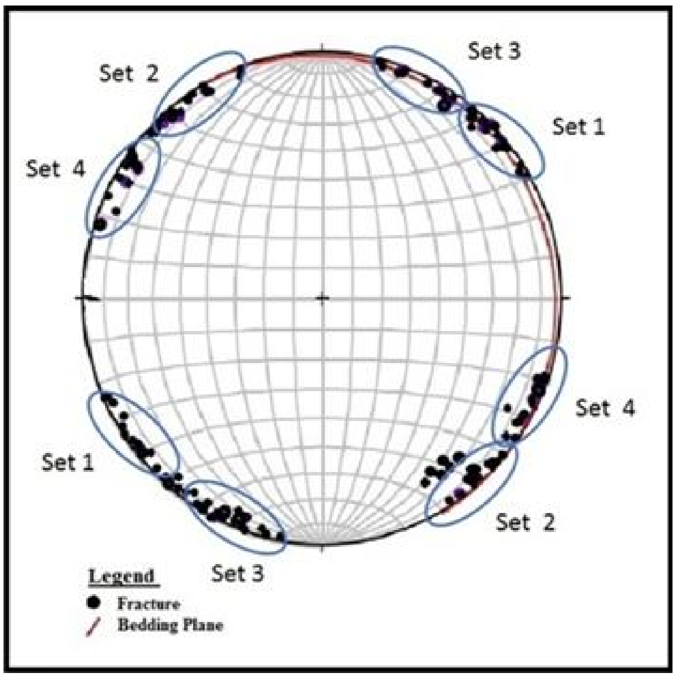

Figure 8: Stereographic projection extension fractures in the study area

Extension fractures are formed parallel to the greatest principal stress σ1 (Hancock, 1985). From the geometry of fractures, it is conceivable to imagine that, through the developments' history of the Arabian plate towards the northeast and towards the north. The main principal stress σ1 was oriented into two main directions. These directions were NE-SW and N-S and, subsequently, the least principal stresses σ3 were orientated in NW-SE and E-W directions respectively. While the middle principal stress σ2 was towards normal to the plane containing (σ1) and (σ3).

CONCLUSION

This study has the following conclusions:

1. The Euphrates River is a combination of fault and joint systems. It exemplifies a sequence of tectonic events that influenced the Arabian plate from the pre-Cambrian to the present time. It contains many articular areas that connect these different systems of joints and faults.

2. The rose diagram for the study area shows different directions of lineaments the dominated direction trend is E-W, and second trend is NW-SE (315) and N-S trend which reflect the effect of Najd and Euphrates faults in the study area.
3. Fractures at Euphrates River basin were separated into a number of sets based on their orientation and Morphology. The major fracture sets were classified into 6 regions along the Euphrates River as in figure (6), in the study area the direction was N70W.
4. On the basis of geometry and Kinematics, fractures were divided into extension sets and shear systems. Shear fractures could have created under a stress regime when maximum principal stress axis was roughly NW-SE (Horizontal) the intermediate principal stress axis (vertical).
5. Two systems of fractures (1) and (2) with (4) sets is directions are extension fractures with almost horizontal beds in the stable shelf (west of Euphrates River).

Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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