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Geography, Geomorphology, Stratigraphy and Tectonics of the Euphrates River Basin

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Abstract

The geography, geomorphology, tectonics, stratigraphy and economic potentials of the Euphrates river basin are given with emphasis on Iraqi parts. The course of the river inside Iraq runs mainly in the Mesopotamian Plain, whereas basin of the river is located in different tectonic zones with different characters. Accordingly, the Quaternary sediments being dominated by the alluvial plain sediments cover large parts of the river's course, whereas the basin area is covered mainly by different rocks types of different ages. The main economic potentials are the existing oil fields, limestone deposits for cement industry and many non-metallic deposits.

Keywords: Euphrates River, Quaternary sediments, Mesopotamian Plain, Economic potential.

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1. Introduction

The geology and topography in the basin of the Euphrates River are given with many satellite images and different maps for clarification purposes. However, the given details in Turkey, Syria and Saudi Arabia are presented more briefly. This article is divided into two main parts, for the course of the Euphrates river and the basin area.

1.1 Geography of the Euphrates River

The Euphrates River inside Turkey, flows in mountainous areas with almost gorge and/ or canyon like valleys; forming favourable areas for construction of many dams. The Euphrates River inside Syria flows in undulatory plains; in its upper reaches. In the central and southern parts, flows alongside some mountains and elevated areas with wide flood plains, which are the north-westwards continuations of the wide plains inside Iraq.

The Euphrates River enters from Syria into the Iraqi territory in the central western part at a town called Al-Qaim (Figure 1), at an elevation of 188m (a.s.l.). The flood plain is wide with many acute meanders, some of them form abandoned ox bow lakes (Figure 2).

The valley of the Euphrates River runs through a rocky terrain, to the south is Ana Mountain, an outstanding morphological feature in the Iraqi Western Desert; whereas to the north is Al-Jazira Plain with undulatory and rolling landscapes, the trend of the river is almost W – E (Figure 2). A dense set of valleys occurs to the south of the river draining the Western Desert into the river. The river continues flowing in a rocky terrain until it crosses Ana Mountain at an elevation of 145m (a.s.l.), and then changes its trend to NNW - SSE until it merges into Haditha Dam Reservoir at an elevation of about 100m (a.s.l.).

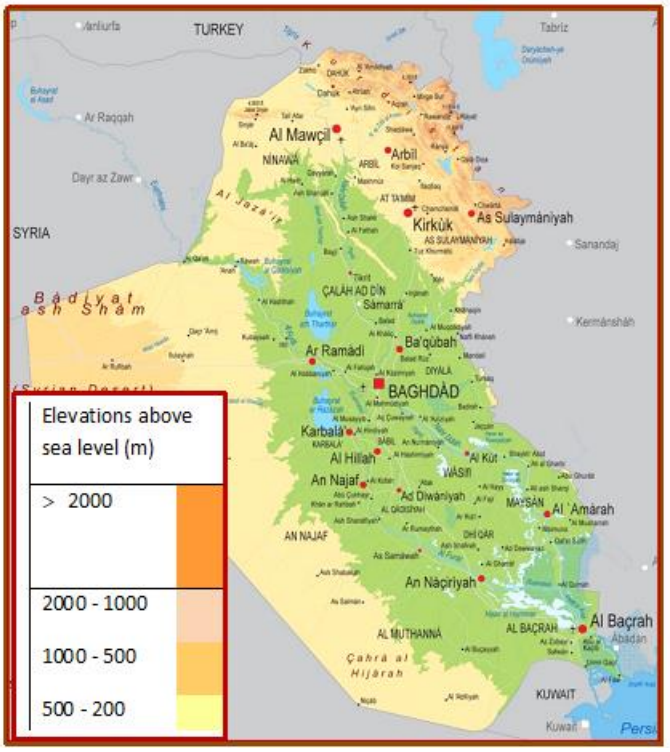

Figure 1: Geographical map of Iraq showing the general relief and the main rivers and their tributaries and distributaries.

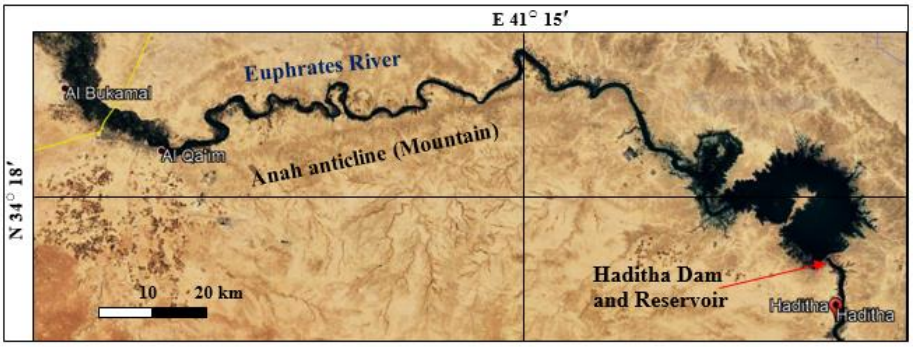

Figure 2: Google Earth image of the Euphrates River, note the dense net of valleys, which drain the Western Desert into the river; also note Haditha Reservoir.

The Euphrates River flows out of Haditha Dam and flow in a rocky terrain with trend of almost N – S. Many large valleys merge with the river flowing from the Iraqi Western Desert, like Hauran, which is the largest valley in Iraq [1], Al-Asadi, Al-Mahamidiyat. After 85km from the dam, at an elevation of 63m (a.s.l.), the river enters the Mesopotamian Plain, between Hit town and Ramadi city (Figure 1).

Near to Ramadi city, there is a channel to divert the water to Al-Habbaniyah Depression which takes from the left bank of the river upstream Ramadi Barrage. Two more canals connect to this created lake; the first returns water to the river and the second is a Flood Escape outlet from Al-Habbaniyah to Al-Razzazah Depression; all are in flat and rolling rocky landscapes. After Ramadi city, the Euphrates River flows in a wide alluvial plain with tens of meandering indicating the maturity of the river. Near Falluja town at an elevation of 45m (a.s.l.), here, the Falluja Barrage was built on the river to feed the extensive irrigation canals networks extending in south-easterly direction, and, also where the (Dhira'a Al-Furat) canal merges with the river; this canal brings supplementary water from the Tharthar Lake to feeds the Euphrates River during low discharge periods in the river. Downstream from the Falluja Barrage the river starts flowing in NW – SE trend for about 63km and at an elevation of 37m (a.s.l.), the river bifurcates into two main branches; an eastern one; called Shat Al-Hilla and western one; called Shat Al-Hindiyah. Both branches flow in a wide flood plain with tens of distributaries and draining channels, until about 6.5km NW of Al-Shanafiyah at an elevation of 17m (a.s.l.), there they merge together forming one main river channel.

Near Al-Shanafiyah, the Euphrates River forms the boundary between the Mesopotamian Plain and the Iraqi Southern Desert and continues flowing in NW – SE trend until 11km west of Al-Samawa city at an elevation of 14m (a.s.l.). There, the river changes its trend towards the East until Samawa city and starts flowing again in NW – SE trend in the Mesopotamian Plain. At Nasiriyah city, the Euphrates River changes its trend to NNW – SSE and after 25km and at an elevation 6m (a.s.l.) it merges in the first marsh called Hor Al-Hammar, near Suq Al-Shuyukh town (Figure 3). Then the river continues its course within the marsh; eastwards until it meets with the Tigris River near Qurna town (Figure 1).

The Euphrates River in the entrance to the Iraqi territory forms the contact between Al-Jazira Province and the Western Desert Province until near Ramadi city, there it flows in the Mesopotamian Province until near Al-Samawa city; where it forms to contact between the Mesopotamian Province and the Southern Desert Province, then flows back again in the Mesopotamian Province until it meets with the Tigris River in Al-Qurna town; forming Shat Al-Arab, which flows in the Arabian Gulf [2]. The gradient of the Euphrates River from Al-Qaim town until Ramadi city; where it enters to the Mesopotamian Plain is 0.12%, and from the Ramadi city until it merges with Al-Hammar Mmarsh is 0.12% and until it merges with the Tigris River in Al-Qurna town is 0.001%. However, the average gradient of the river in Iraqi territory is 0.17%, the height difference is 183m and the length is 1060km [3].

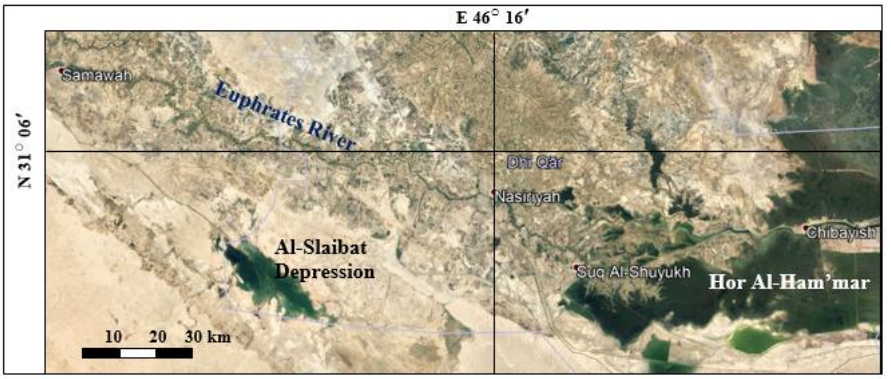

Figure 3: Google Earth image showing the course of the Euphrates River between Samawa and Al-Nasiriyah cities and Hor Al-Hammar.

2. Geological Setting of the Euphrates River

The geological setting of the areas through which the Euphrates River flows is briefly reviewed using the best available data; mainly based on the geological maps of different scales and reports compiled by Iraq Geological Survey (GEOSURV) staff. However, in Turkey, Syria and Iran, published geological maps and satellite images are used to present; briefly the geological data. The geological setting includes:

1) Geomorphological aspects
2) Tectonic and structural Geology,
3) Stratigraphy.

Each subject deals separately with the two rivers.

2.1 Geomorphology

The used data for describing the Geomorphological aspects inside Iraq are mainly acquired from the Geomorphological Map of Iraq [4] and the Geological Map of Iraq [2].

The Euphrates River inside Turkey flows in very rugged areas forming anticlinal ridges and erosional pediments. Many levels of terraces are developed along the course of the river and its main tributaries.

The Euphrates River inside Syria flows in undulatory plains forming mainly depositional pediments with distinct river terraces and wide flood plains.

The Geomorphological units and forms of the course of the Euphrates River inside Iraq are briefly described; hereinafter.

The main Geomorphological fluvial units of the river are the terraces and flood plain. Two levels of terraces are developed in the upper reaches of the river which continues downwards until Al-Falluja town [4]. Moreover, poorly developed anticlinal ridges, plateaus, erosional pediments and flat irons are developed, a good

example is along the northern limb of Ana anticline near the city of Ana at the upper reach of the river in Iraq [5] (Figure 4).

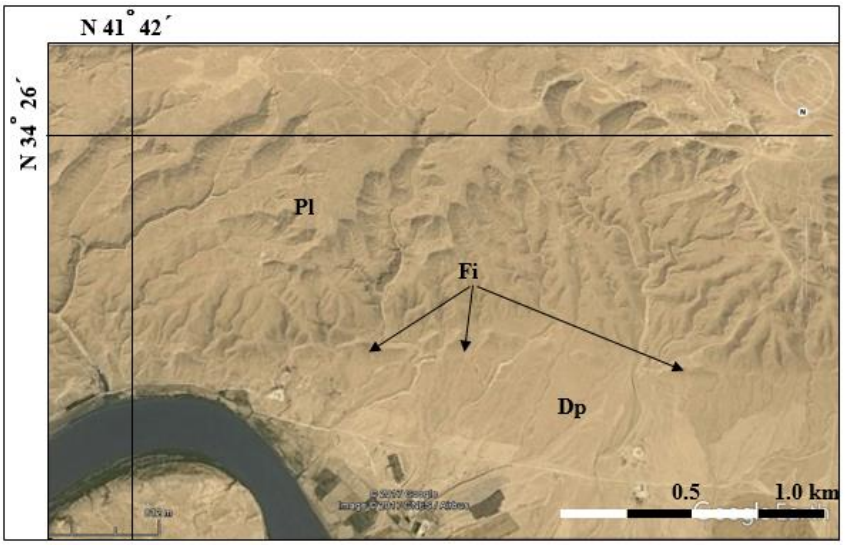

Figure 4: Google Earth image facing south, note the deeply incised valleys, plateaus (Pl), flat irons (Fi) and the depositional pediments (Dp).

Downwards from Al-Falluja, where the last terrace deposits were laid down during Pleistocene, the Euphrates River flows in a wide flood plain with tens of meanders, some of them are abandoned forming ox bow lakes and/ or are dried. After that, the river flows in the wide Mesopotamian Plain, which is characterized by depressions of different sizes, crevasse splays, sheet run off marshes (both active and dry), estuarine sabkhas sediments, and in the extreme southern part of the course of Shat Al-Arab, tidal flat and inland sabkha sediments [6].

2.2 Tectonics and Structural Geology

The main tectonic zones through which the Euphrates river flows are described, besides the main structural features, such as anticlines, faults, subsurface anticlines (Figure 5). However, the tectonic units inside Turkey, Syria and Iran alongside the Tigris and Euphrates rivers with their tributaries are briefly mentioned. Moreover, the Neotectonic activities inside Iraq are also briefly described for both of the Tigris and Euphrates rivers; emphasizing on the Mesopotamia Plain, which is a very mobile subsiding trough.

The Euphrates River inside Turkey; in its upper reaches flows mainly in the Anatolide – Turoside Block, and crosses the Northern and Eastern Anatolian faults in its northern and western reaches. Moreover, the river crosses in it is southern reaches inside Turkey the Bitlis – Zagros Suture Zone.

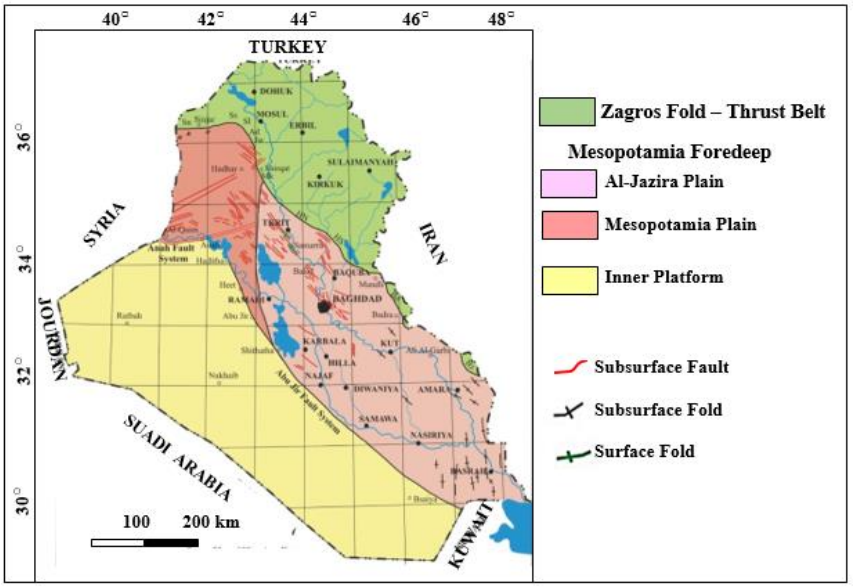

Figure 5: Structural Map of Iraq, showing the Mesopotamia Foredeep. (After [7]).

The Euphrates River inside Syria flows mainly in the Arabian Plate; represented by the Aleppo Plateau. In its upper reaches, it is affected by Irbid Rift; whereas in the central reach it is affected by the Palmyrides. The river in its southeastern reach; before entering into Iraq flows in the Azraq Graben, which is the continuation of the Ana Graben in Iraq.

The Euphrates River where it enters the Iraqi territory from Syria forms the contact between two tectonic zones, Al-Jazira and Western Desert zones (Figure 5) and continues until Haditha town. There, it flows entirely within Al-Jazira Zone until west of Ramadi city. There, it flows in the Mesopotamian Zone and continues until it merges with the Tigris River.

The Euphrates River, in its upper reaches, flows parallel to Ana anticline in W – E trend (Figure 2), it is the only anticline along the course of the river within the Iraqi territory. Moreover, the Euphrates River flows almost parallel to the Abu Jir – Euphrates Fault Zone; between Al-Najaf and Al-Samawa cities (Figure 5).

2.3 Stratigraphy

The type, age and geological formations along which the course of the Euphrates River flows inside Iraq are described depending on [2, 8, 9]. The geological map of the river course is shown in Figure 6.

However, the exposed rocks alongside the course of the river and its tributaries inside Turkey, Syria and Saudi Arabia are very briefly mentioned too.

The Euphrates River in Turkey, in its upper and western reaches, flows in Mesozoic metamorphic and Tertiary volcano – sedimentary rocks. South of Malatya city, the river flows in Eocene limestones and locally in Plio - Quaternary alluvial basin, until it enters to the Syrian territory.

The Euphrates River in Syria flows within the Paleogene marl and marly limestone until the central parts, then it flows in the Neogene sandstones, conglomerates and limestone, with two small volcanic necks of basalt flows northwest of Der Az Zor. The Euphrates River in its entrance to the Iraqi territory from Syria runs in the Euphrates Formation (Figure 6), the formation consists of limestone, dolostone and marl. The age of the rocks is Lower Miocene (23.03Ma). It continues flowing within this formation until the old Ana town, there it flows in the rocks of the Ana Formation, which consists of very hard limestone; locally includes corals.

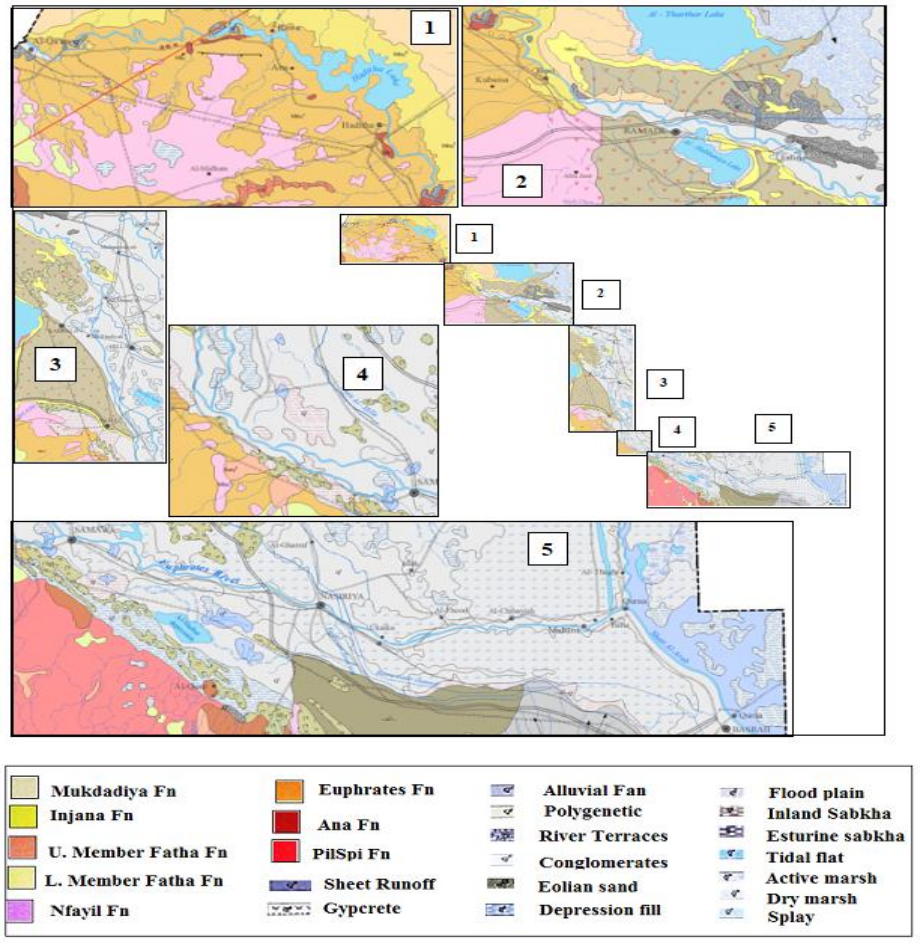

Figure 6: Geological map of the Euphrates River's course. The small portions show the geographic relation between the five parts of the geological map. (After [2]).

Near Alus town, between Haditha and Hit towns on the left side of the river, the rocks of the Fatha Formation are exposed. The formation consists of cyclic deposits of green marl, reddish brown claystone, limestone and gypsum, the age is Middle Miocene (15.97Ma). Near Hit town, west of Ramadi about 70km, the river flows entirely within the rocks of the Fatha Formation.
Between Hit town and Al-Ramadi city, on the right side of the river, the rocks of the Nfayil Formation are exposed. The formation consists of an alternation of green marl and limestone; the age of the formation is Middle Miocene (15.97Ma).
Northwest of Al-Ramadi city by about 15km, the Euphrates River runs in the Mesopotamian Plain and continues until it merges with the Tigris River near Al-Qurnah town. The sediments of the Mesopotamian Plain consist mainly of silt and clay; however, locally some depressions occur. They may have some organic soil with silt and clay. It is worth to mention that after Al-Nasiriyah city, the Euphrates River starts flowing in marshy area. The sediments there are highly contaminated with organic materials. The age of all those sediments is Holocene (11.7Ka).

3. Mineral Resources

The present mineral resources along the course of the Euphrates River in Iraq and their tributaries are mentioned hereinafter.
The following mineral resources and/ or industrial rocks occur along the course of the Euphrates River. The presented data are acquired mainly from (Al-Bassam, 2007).

3.1 Limestone

Limestone is the main constituent of the Euphrates Formation; the formation is widely exposed along the course of the river (Figure 6). The main uses of the limestone are mentioned hereinafter.

a) **Cement Production:** Four cement plants are located along the course of the Euphrates River (Figure 7). The first one is Al-Qaim cement plant; it uses limestone from the Ratga Formation; however, the quarry is very far from the cement plant. The other three plants are Al-Fallujah, Al-Hindiyah and Al-Kufa cement plants. They all use the limestone quarried from the exposures of the Euphrates Formation.
b) **Rock Slabbing Plant:** One rock slabbing plant is located between Haditha and Haqlaniyah towns. The used limestone is quarried from the exposures of the Euphrates Formation. The plant; however, was abandoned due to difficulties in the limestone quarry. Therefore, it is used nowadays as rock slabbing plant for igneous and metamorphic transported from different localities.

3.2 Uranium

Uranium is detected in the Euphrates Formation at Al-Qaim vicinity and south of Al-Najaf at Abu Skhair vicinity. The latter is more concentrated and more promising.

3.3 Oil

Although "oil" is not a mineral; but, it is mentioned as "Mineral resources". On the other hand, a "mineral resource" is anything that is economically valuable which are extracted from the earth. Many oil fields with different annual production and different oil types are located along the course of the Euphrates River (Figure 8). All of the oil fields are subsurface fields, such as Fallujah, Al-Kifil, Subba, Qurna West and Rumaila North oil fields.

3.4 Clay

Clay occurs in enormous amounts in the flood plain of the Euphrates River and the Mesopotamian Plain. The main use is in brick production, many brick plants are located along the course of the Euphrates River; such as in Al-Hilla city, Al-Mahaweel town.

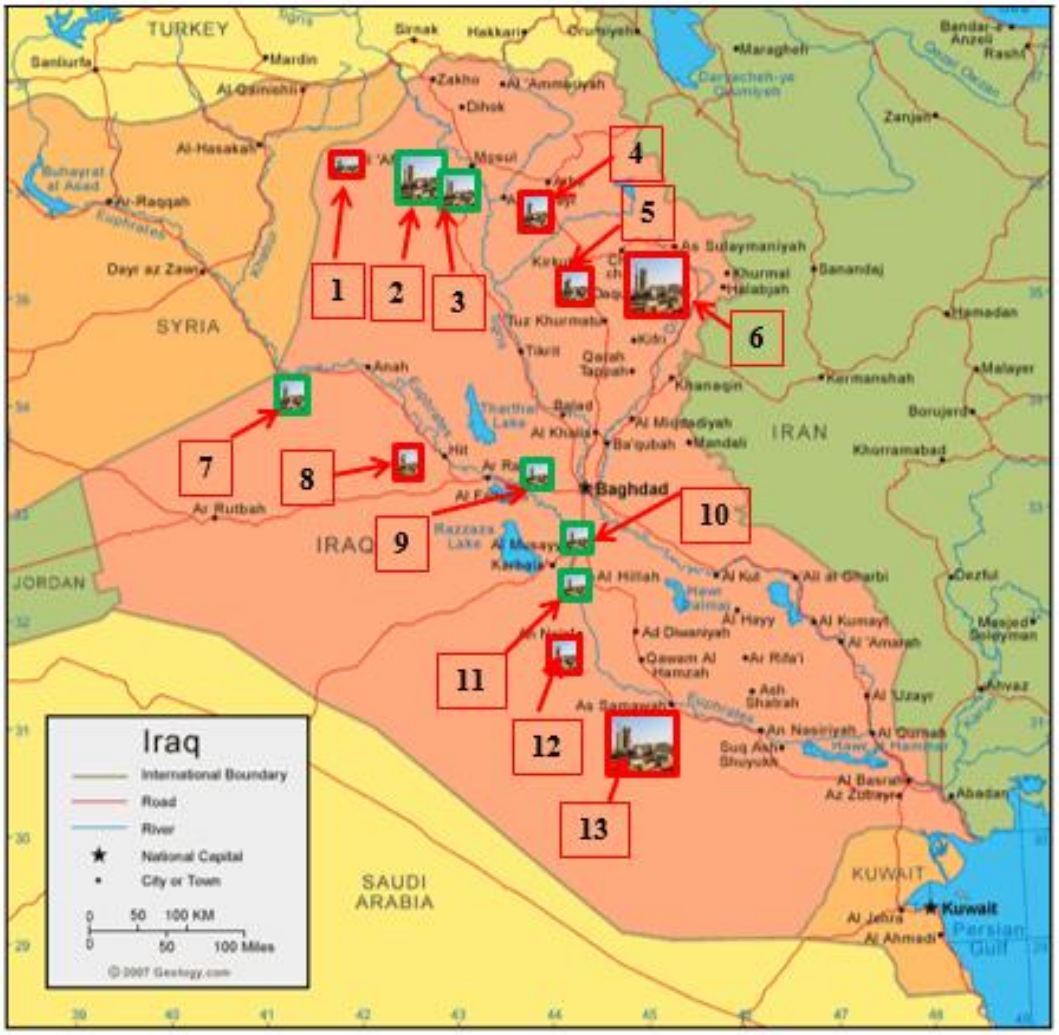

Figure 7: Cement plants in Iraq. In green are those located along the Tigris and Euphrates Rivers, in red are plants far from the river courses. 7= Al-Qaim, 8= Kubaisa, 9= Falluja, 10= Al-Hindisya, 11= Karbal, 12= Al-Najaf, and 13= Samawa complex.

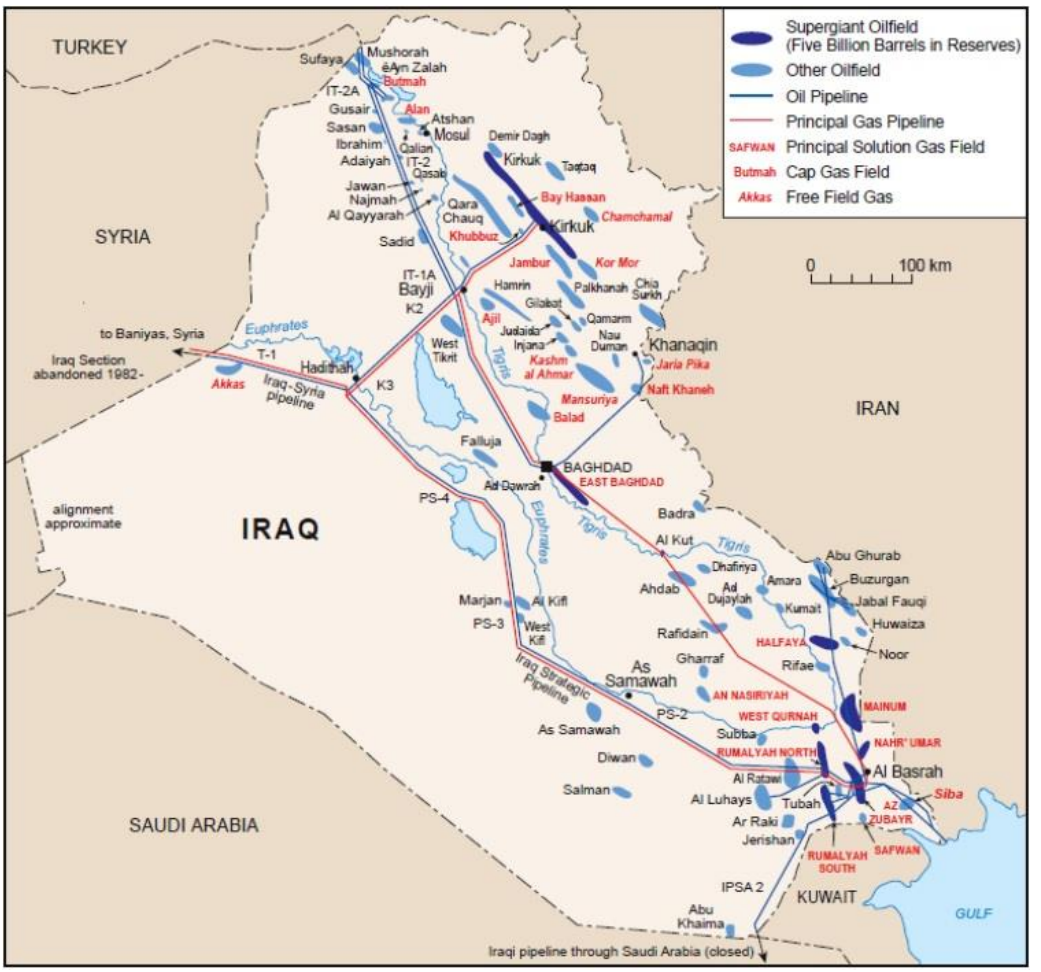

Figure 8: Distribution of oil fields in Iraq.

4. Sea Level Changes and course of the Euphrates River

There are some discrepancies in the assumptions between researchers as the shore line of the gulf and the course of the Euphrates River is concerned, even in the works of the same authors. For example, [10] assumes that the shoreline was near Hit; along the Euphrates River and at Samarra; along the Tigris River during 8000 – 6000B.C., which are about 600km northwest and north of the present shoreline. Moreover, he assumes that the Tigris and Euphrates rivers were flowing directly into the gulf without being merged together during 325B.C. This means that the shoreline was more northwards than the present shoreline; otherwise, the two rivers couldn't flow separately into the Gulf. However, he didn't mention how far the shoreline was. It is worth to mention that before 8000 years the Ubaid settlements were close to the location of Ur which was very near from the shoreline [11].

The time of reaching the present shoreline location is again quite different from the mentioned assumptions by different authors. For example, [12] claimed the present shoreline location was 6000B.C. Whereas, during 6000B.C. the shoreline was 360km north of the present location according to [13], and between Nasiriya and Amara [14, 15, 16]. Moreover, [12] claimed that before reaching to the present shoreline, the whole Gulf was dry and the Tigris and Euphrates River were flowing into the Gulf directly. This assumption was confirmed only by [14]. However, this agrees with the theory that the early Sumerians had crossed the Gulf which was dry at that time coming from a place in Baluchistan and they settled in Bahrain (Dilmun) before moving to Mesopotamia [17]. [14] claimed that until 14000B.C., the whole Gulf area was a dry land. Later on, the sea started forward movement which is exactly the opposite of all other reconstructed scenarios of different authors.

[18] mentioned that the shoreline of the Gulf was 1440km southeast of Baghdad before 10500B.C., and it was 250km southeast of Baghdad along the Tigris River (near Amara city) and 60km southwest of Baghdad along the Euphrates River (near Hilla city). Although they use palynological evidences like their colleagues [15] but they reached to very different results as the shoreline of the Gulf is concerned.

Another abnormal assumption is presented by [15]. They constructed the shoreline during different time spans depending on the present ostracods and palynology. The abnormal presentation is that they extended the shoreline only along the Tigris River; not along the Euphrates River. This means the course of the Euphrates River was higher than that of the Tigris River, therefore, the gulf extended only towards the Tigris River. Moreover, this means that the ancient city of Ur was never been located along a shoreline, which is not in accordance with the majority of carried out archeological and geological studies.

Another significant issue which needs discussion is the changing of the river courses during the Pleistocene and Holocene. There is a big difference between the considered reasons between the archeological and geological studies. The archeological studies assume that all the happened changes in the river courses are related to major floods and/ or constructed irrigation canals (Ellison, 1978). Whereas, geological studies assume that the main reason for changing of the river courses is the Neotectonic activities which are mainly related to the growth of the subsurface anticlines [7, 19, 20, 21, 22, 23]. Moreover, the activity of the Abu Jir – Euphrates Active Fault Zone also has played role in shifting the course of the Euphrates River (Figure 9) and is still shifting the river course more towards northeast. Some large alluvial fans also have shifted the river courses during their growth, especially during Late Pleistocene and Holocene. A good example is Al-Batin alluvial fan, which has shifted the course of the Euphrates River [24, 25]. However, the influence of major floods and the mechanism of river hydraulics, especially during large floods are also considered in majority of geological studies. The presence of main irrigation canals which were constructed during early civilizations are also considered too in geological studies as main factor which had contributed in shifting of the river courses [26, 27]. The humid conditions associated with very heavy rain showers during wet stages of the Pleistocene and even early

Holocene also had contributed in changing the river courses. This is attributed to the erosional forces and the weight of the carried sediments in entrenching the courses of the rivers into more straight courses, especially when acute meanders had existed in the river courses, where the irrigation canals were constructed perpendicularly on large meanders. This is called rapidly varied flow [28].

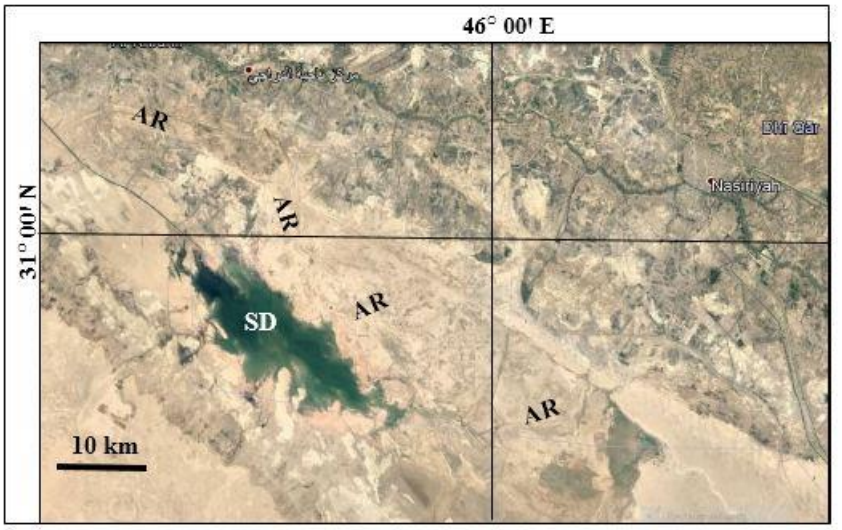

Figure 9: Satellite image showing abandoned river course (AR) of the Euphrates River. Note Al-Slaiabt Depression (SD) which was most probably an old marsh.

5. Tributaries of the Euphrates River

The geological aspects along the tributaries of the Euphrates River are described briefly. Since there is no tributary of the Euphrates River inside Iraq; therefore, only some main valleys, which drain the Iraqi Western and Southern Deserts are mentioned. In Turkey, the tributaries are already mentioned within the main course of the rivers.

The Euphrates River inside Syria has two main tributaries Balikh and Al-Khabour (Not the same tributary of the Tigris River) (Figure 10). The first one merges with right side of the river 20km south of Jirablus city, the second one merges with the Euphrates River at Al-Raqqa City, whereas the third one crosses Al-Hasaka city and merges with the Euphrates River at Der Az-Zor city. The two tributaries of the Euphrates River; inside Syria has almost N – S trend (Figure 10), which is perpendicular to the Turoside tectonic regime. Most probably are tectonically controlled as are the tributaries of the Tigris River inside Iraq [24]. The three tributaries of the Euphrates River flow in Paleogene marl and marly limestone; however, Al-Khabour River flows in the Neogene sandstones, conglomerates and limestone in its lower reaches. It is worth mentioning that many large valleys merge with the river in its lower reaches; among them are wadi Al-Hay and wadi Suwab (Figure 10).

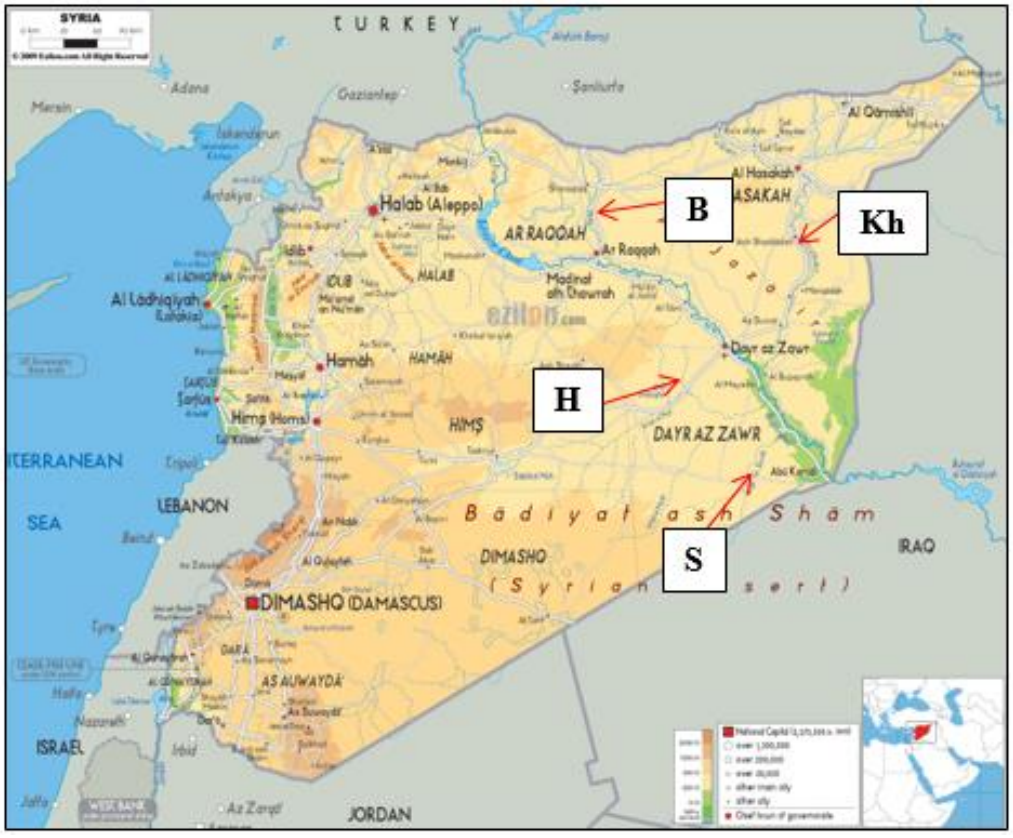

Figure 10: General map of Syria showing the trend of the Euphrates River and both tributaries, Balikh (B) and Al-Khabour (Kh). Also note the main valleys; among them are Al-Hay (H) and Suwab (S).

The Euphrates River inside Iraq has no tributary; however, it has tens of large valleys (Figure 11) draining the Iraqi Western and Southern Deserts; among them are: Al-Ratgah, Al-Mana'I, Akash, Chab'bab, Kahzgah Al-Gharbi and Khazga Al-Shargi, Al-Qaser, Al-Fhaimi, Al-Akhdhar, Haqlan, Hauran, Al-Aasadi, Mahamadiyat, Al-Ghadaf, Al-Ubayidh, Al-Khir, Al-Jil, Al-Aqrawi…etc. The largest one among those valleys is Hauran [1, 21]. The valleys supply considerable amount to the Euphrates River during rainy seasons, although the amounts are drastically have decreased in recent years. This is attributed to Global Climate Changes and to construction of many dams on the valleys which outflows into the river.

According to the local people living near the outfall point of wadi Hauran in the Euphrates River, the flood water from Hauran overflows in some instances the opposite bank of the Euphrates River forming a barrier to the flowing water in the river (1972, personal communication with the local people).

The valleys, in the Western Desert flow in S – N trend then the courses change to SW – NE, and then to W – E. However, east of wadi Al-Ubayidh, (Figure 10) the trend of the valleys return to SW – NE again; starting from Wadi (valley) Al-Khir, which forms the boundary between the Western and Southern Deserts.

Figure 11: General map of Iraq showing some of the main valleys in the Western and Southern Deserts. H=Hauran, G = Al-Ghadaf, U = Al-Ubayidh, K=Al-Khir, J-Al-Jill, A= Al-Aqrawi.

Part of the valleys of the Western Desert originate from Saudi Arabia and very rarely from Jordan, while part of those of the Southern Desert; originate from Saudi Arabia (Figure 11). The valleys in the western part of the Western Desert flow mainly in carbonate rocks of Eocene age (Ratga Formation; equivalent of the Dammam Formation. Those in the central part of the Western Desert, flow mainly in carbonate rocks of Miocene age (Ghar, Euphrates and Nfayil formations). Those of the eastern part of the Western Desert, flow in carbonate rocks of Cretaceous, Paleocene, Eocene and Miocene in age (Hartha, Tayarat, Akashat, Um Er Rdhuma, Ratga, Dammam, Ghar, Euphrates and Nfayil formations [2].

The valleys in the Southern Desert, flow mainly in carbonate rocks of Paleocene, Eocene and Miocene in age (Um Er Radhuma, Dammam, Ghar, Euphrates and Nfayil formations) [2]. Those valleys flow in highly karstified rocks forming karst topography, which has greatly influenced on the drainage system [2]; moreover, has caused development of large depressions; such as Al-Salman Depression [29]. Therefore, considerable amount of the flood water recharge the groundwater aquifers [30].

6. Mineral Resources of the Euphrates River's Tributaries

The existing mineral resources along the tributaries of the Euphrates River are briefly described hereinafter.

As the Euphrates River has no tributaries inside Iraq; therefore, the existing mineral resources along the main valleys, which drain the Western and Southern Deserts are mentioned briefly hereinafter. The main occurrences of different mineral resources are presented in Figure (12).

6.1 Phosphate

Phosphate occurs within the Akashat Formation, which is exposed along wadi (valley) Akash. The mines of the phosphate are located along the banks of wadi Akash along the Iraqi –Syrian borders. The phosphate is transported by trains from the mines to Al-Qaim Complex south of Al-Qaim town along the Euphrates River [31, 32].

6.2 Limestone and Dolostone

Limestone for cement production occurs in the Ratga and Euphrates formations in enormous amounts. Both formations are exposed along many valleys in the Western Desert. The quarries of Al-Qaim cement plant are located along the course of wadi Akash and wadi Suwab [31]. Limestone quarries of Kubaisa, Karbala, Kufa, Najaf and Samawa cement plants are within the Dammam and Euphrates formations, which are exposed along the courses of wadi Al-Ghadaf, wadi Al-Ubayidh and other small valleys; all drain into the Euphrates river. Moreover, limestone and dolostone are quarried and used as construction materials and as decorative stone. Locally, they were crushed and used as aggregates as sub-base during construction of the High Way No.1, especially in Kilo 160 – Rutba Vicinity and westwards. Moreover, limestone of the Ratga Formation is used as rock ballast for the rail way constructions [33].

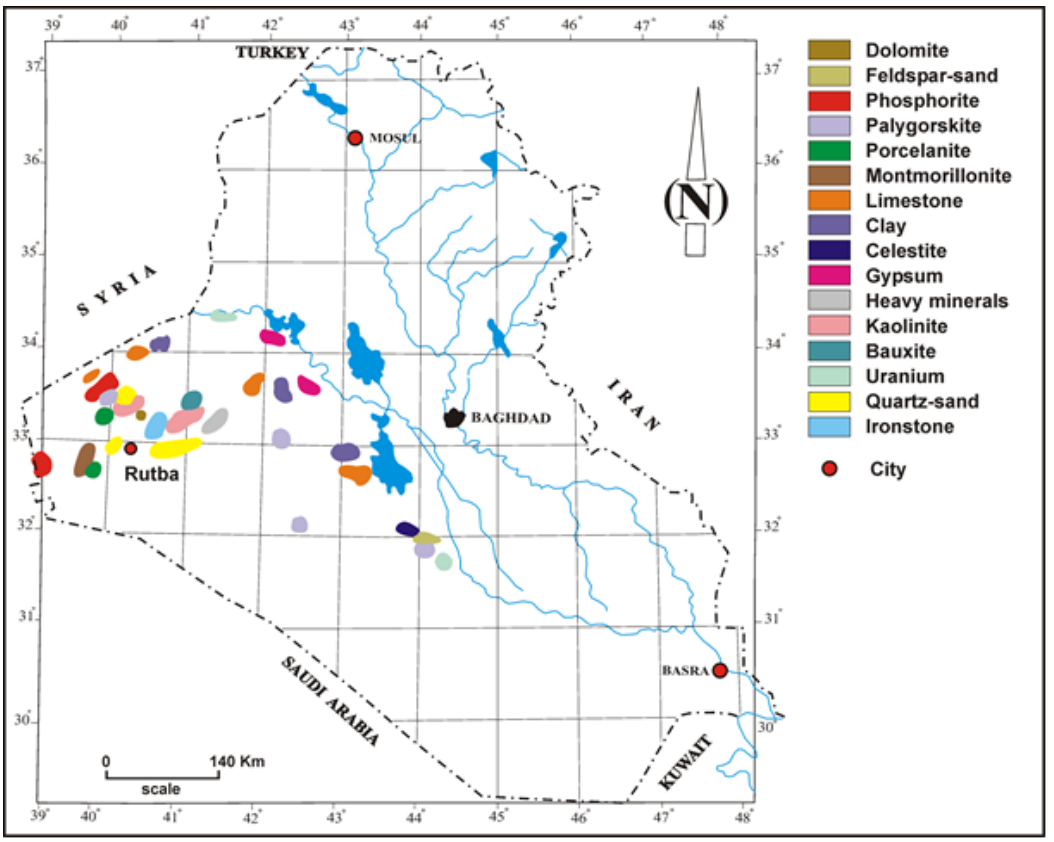

Fig.12: Distribution of Mineral resources in the Western Desert of Iraq (After [31]).

6.3 Uranium

Uranium is present in the rocks of the Euphrates Formation in Abu Skhair vicinity, south of Al-Najaf City [34, 35]. A shaft was dug to excavate the raw uranium; however, it was dumped after 1991.

Uranium is also present in the phosphate deposits, which are exposed in Akashat Formation in Akashat vicinity, NE of Rutba [36].

6.4 Gas

Natural gas was discovered in Akass filed south of Al-Qaim along wadi Al-Mana'i and wadi Al-Ratga (Figure 8). Many wells were drilled during late nineties of the last century; however, it is not yet fully discovered.

6.5 Glass-sand

Glass-sand occurs in enormous amounts with the Rutba Formation. A main quarry for glass-sand exists at Urdhuma; 12km west of Rutba city [9]. It is pure quartz sand; reaching 98% purity. [31]. The main use of the sand is in glass industry at Ramadi city.

6.6 Sedimentary Iron

Sedimentary iron of different percentages occurs in Hussainiyat Formation; at Hussainiyat vicinity along wadi Al-Hussainiyat [31]. The valley is one of the main branches of wadi Hauran. The sedimentary iron is quarried and used in cement plants of the southern Iraq.

6.7 Kaolinite

Kaolinitic claystone is restricted in occurrence to the Western Desert and in age to the pre-Cretaceous units. The upper parts of the Ga`ara Formation (Permocarboniferous) in the Ga`ara Depression are characterized by kaolinitic claystone deposits of various types including white and colored varieties. They also occur in the lower parts of the Hussainiyat Formation (Early Jurassic) along Wadi Hussainiyat and in the Amij Formation (Middle Jurassic) at Wadi Amij [31, 37].

6.8 Montmorillonite and Palygorskite Claystone

Montmorillonite and palygorskite of the Late Cretaceous age are present in the Digma Formation, it is exposed along the western rim of the Gara Depression and southwards along the banks of wadi Hauran [9]. These claystones are originally black shales, rich in carbonaceous matter, they were oxidized to yellow and green claystones in surface and near-surface sections [31].

6.9 Karst Bauxite

Bauxite and bauxitic kaolinites were discovered filling up to 70m deep karsts in the carbonates of the Ubaid Formation (Early Jurassic) [31] at Al-Hussainiyat vicinity along the course of wadi Al-Hussainiyat, which is a main branch of wadi Hauran [9]. The bauxite was quarried at Al-Hussainiyat vicinity until 2003 and was used mainly as drilling media in the drilled boreholes for geotechnical purposes.

6.10 Gold

Since early decades of the last century, the occurrence of gold in the Western Desert was a matter of debate. The following paragraph briefs the attempts of finding gold in the Western Desert “Iraqi geologists have been working to figure out locations and quantities of gold deposits. Some have found occurrences of gold in the Gaara formation consisting of ferruginous sandstones and ironstones of the Gaara depression in the western desert of Iraq. Studies reveal that in 1934, McFayden was the first to convey the possibility of finding gold in the Gaara sandstones. However, his investigations could not prove the presence of gold deposits. This was long forgotten until in 1984 when two geologists, Kettanah and Tobia accidently discovered the occurrence of gold while looking for presence of iron. In 1986, Al-Bassam collected a number of samples from Chabid Al Abid region of Gaara depression and concluded that the proportion of gold found in the samples was not commercially viable. Later in 1999, another study by Mustafa in the same area

showed that the samples from region did contain adequate concentration of gold. The above research is documented by Mazin M. Mustafa and Faraj H. Tobia [38].

6.11 Zirconium and Titanium

Zirconium and Titanium with some other heavy minerals were found in the valley fill sediments of some large valleys in the Western Desert and within the Amij Formation (Middle Jurassic). The Amij Formation is exposed northeast of Rutba town (Sissakian and Fouad, 2012). Mahdi and Al-Mukhtar (2006) reported about the presence of considerable amount of zirconium and titanium in the Amij Formation.

6.12 Gravel and Sand

Gravel and sand occur in enormous amounts along the courses of the main valleys of the Euphrates River. The gravel and sand are mainly present as valley-fill sediments, in form of pebbles (for the gravels) of different sizes, forms, shapes and lithology. They are quarried, sieved and washed in enormous amounts and used for different constructional purposes.

7. CONCLUSIONS

Since this article is a review article; therefore, the main conclusions are related to the changes in the river course. The authors believe that the main reason for that is the growing up of the subsurface anticlines. However, the role of the large floods and construction of historical irrigation cannels cannot be ignored. Moreover, the Euphrates River basin including the tributaries and main valleys has a very significant economic potential, especially, non-metallic minerals.

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